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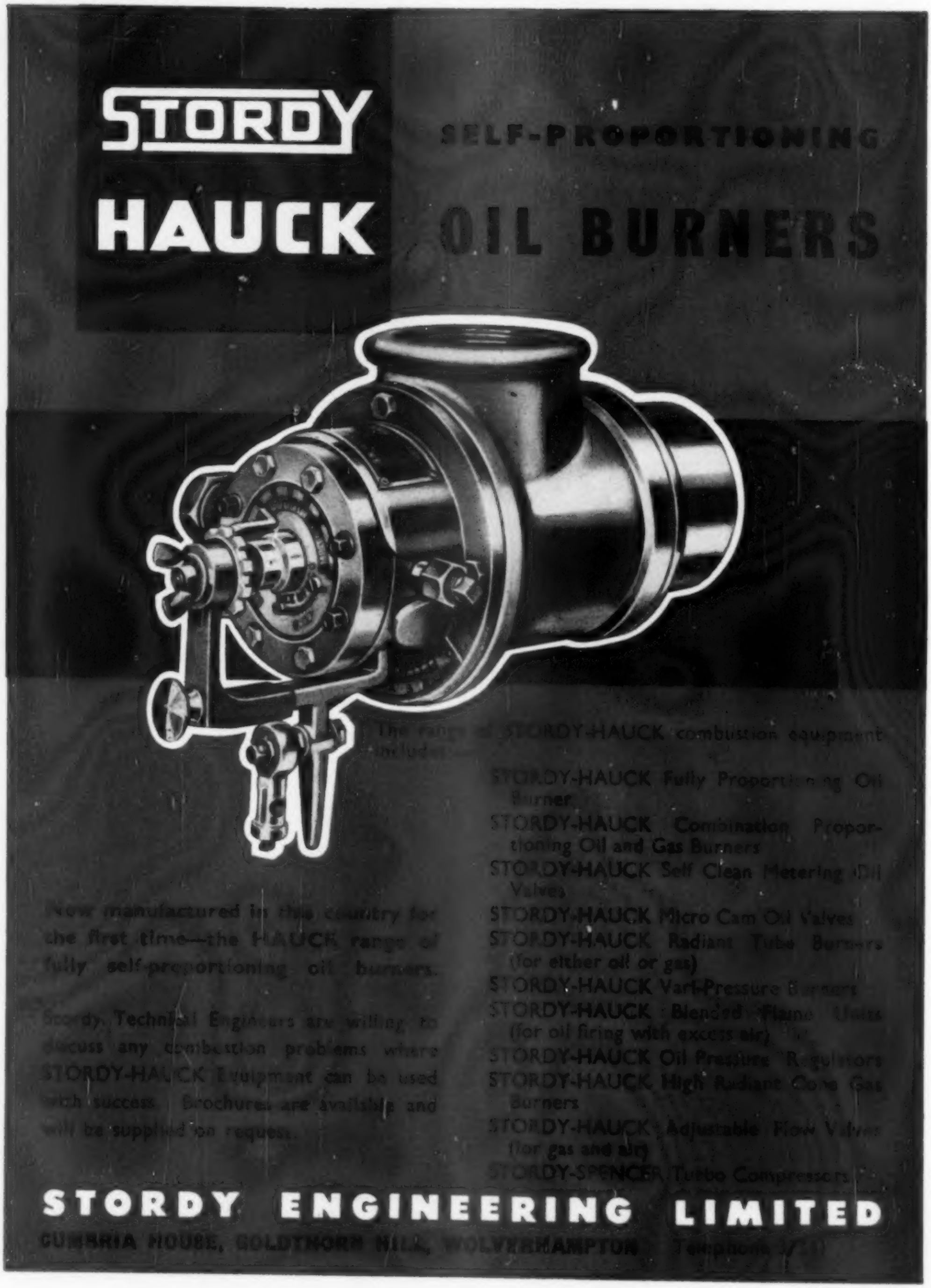
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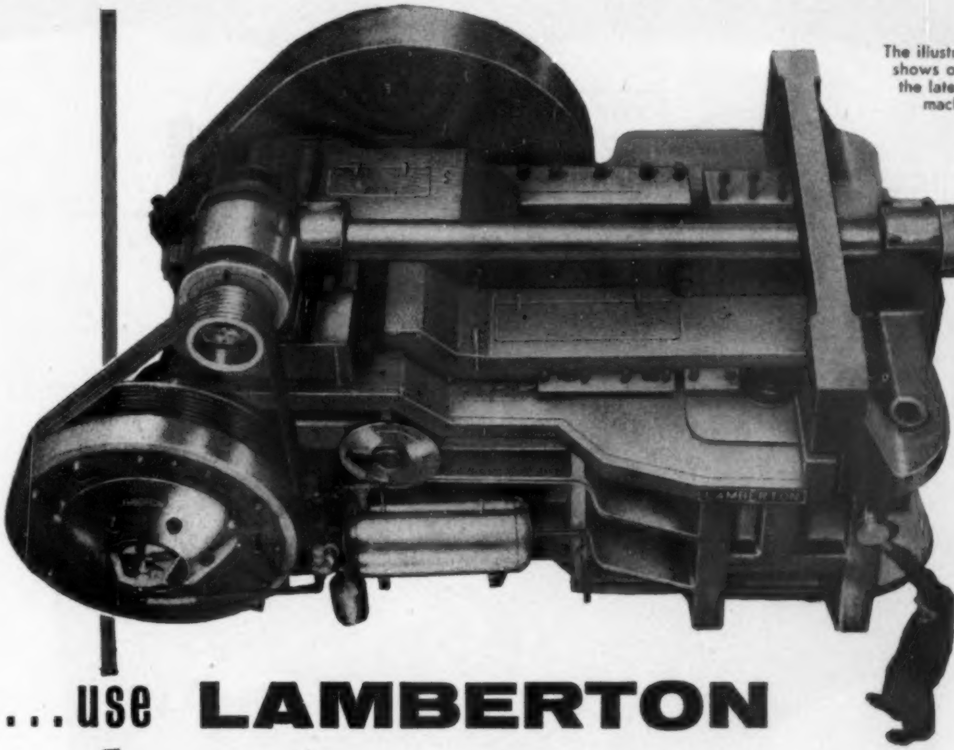

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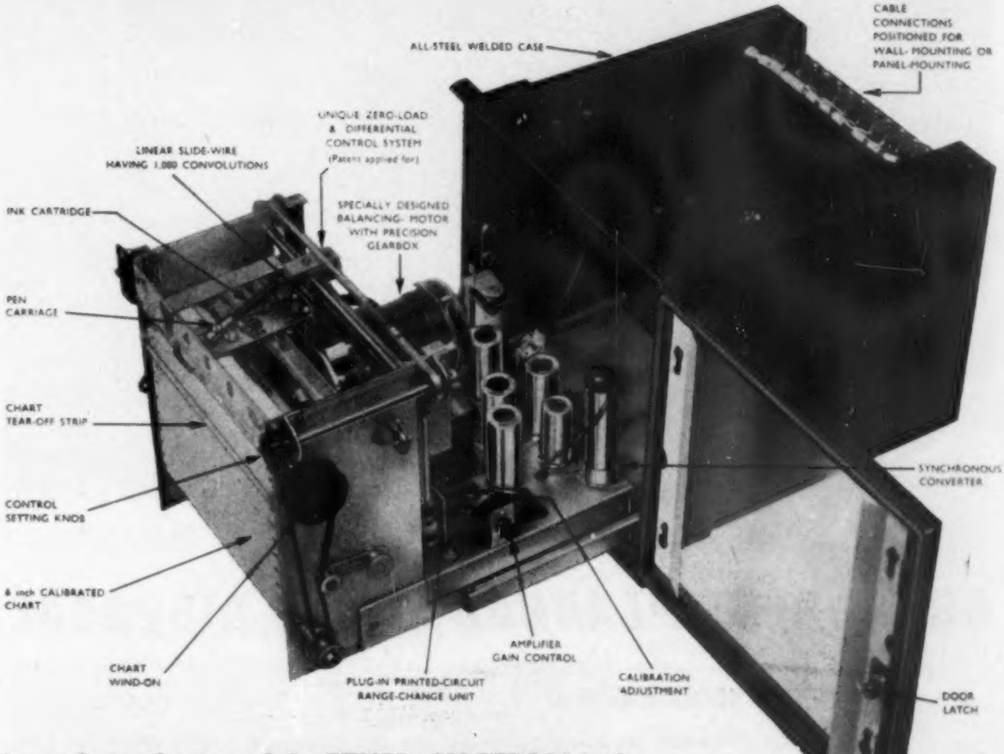

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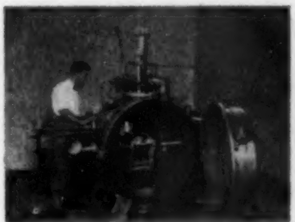

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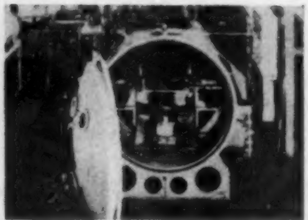

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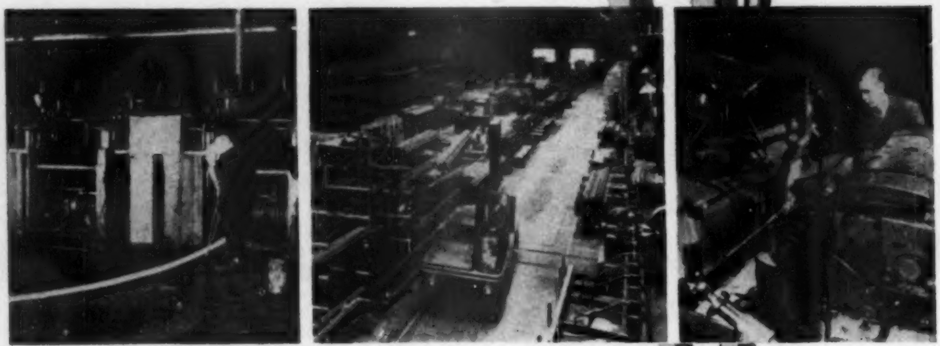

February 1960

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metal treatment

and Drop Forging

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CONTENTS

This journal is devoted to metals—ferrous and non-ferrous—their manufacture, properties, heat treatment, manipulation, testing and protection, with research work and development in all these fields

Hazard

FROM time to time, hard things have been said in these pages about certain propaganda films issued by the British steel industry. We therefore welcome the opportunity of unreservedly expressing our appreciation of a recent film sponsored by the British Iron and Steel Federation. This film—' Hazard '—tells an exciting story of how two young steelworkers on a climbing holiday in the Dolomites met with a dramatic near catastrophe. Although the film was produced in the interests of industrial safety and is intended primarily for showing to new workers entering the steel industry, it is not a teaching film. It offers no advice on hazards to be avoided or safety rules to be observed but instead aims deeper, at a man's whole attitude to safety. It holds a lesson not only for the young worker in the steel industry but for all workers in any industry. The fact that it is able to put across its message and still remain good entertainment is a measure of the success with which its producers must be credited.

A publication which is playing an important part in spreading ideas on accident prevention in industry is the magazine ' Safety, ' also published by the British Iron and Steel Federation. An article appearing in the November, 1959, issue records an interview between journalist Robert Kee and William Carron, president of the Amalgamated Engineering Union, in which Mr. Carron gives his views on accident prevention.

Some of Mr. Carron's remarks on the importance of the worker's attitude to both his own safety and that of others might almost be a commentary on some of the sequences in the film, or alternatively the film could be said to illustrate Mr. Carron's comments. Very much to the point, for example, are the following remarks on protective clothing.

' I think the trouble is that, with safety, we have a case of familiarity breeding contempt. I think everybody connected with industry knows how difficult it is initially to persuade people to adopt what eventually comes to be regarded as an elementary safety measure. One knows that a generation which has become accustomed to certain habits, a certain environment and so on and so forth, is most reluctant to forsake them even though they may be bad, but a succeeding generation having been educated to other necessities adopts a different attitude. We can see that, for instance, in the use of goggles to protect eyes. Initially, it was a most difficult job. In fact, in many cases management had to resort to threats of disciplinary action if people didn't wear them.

' During the war when we had a lot of " green " labour, it was extremely difficult to get them to wear certain types of protective clothing. Where there was an experienced management handling the problem with a good insight into human nature and where the protective devices were designed consistent with good looks, there was much less difficulty in getting acceptance.

' I'd say in some fields, in safety, we're not far behind in thinking and operation. I think a lot of people on the workshop floor in industry generally do think of the other fellow already. For instance, in the minds of people such as crane drivers and slingers there's a very high consciousness of their responsibilities to everybody. That's my shop floor experience, anyway. But to the average individual who might just drop a bolt down in a gangway upon which someone might slip and fracture a thigh or something of that description—well, there's nothing deliberate about it, it's just that they haven't this right attitude of mind. And to help them get that we've got two main factors to contend with: our natural British traditionalism and this business of familiarity breeding contempt.'

Perhaps we may hope that the generation growing up into a world where the use of radioactive substances is becoming increasingly widespread will be forced to learn the right attitude of mind—contempt in this context will carry inevitable penalties.

Russian forging journal

A NEW RUSSIAN JOURNAL devoted to forging—*Kuznechno-Shtampovochnoe Proidvodsto*—made its appearance in January of last year. The editorial reports that at the 21st session of the Russian Communist Party Mr. Krushchev specifically mentioned the forging and stamping industry as a special field for expansion of mechanization and automation. In this context the development of forging manipulators in the U.S.S.R. has scarcely been developed, especially for heavy workpieces, and such manipulators with programmed control will receive special attention. In general, the start of this new journal represents a considerable increase in the attention devoted to stamping and forging in the Soviet Union. The first number (1959, **1**, No. 1) is divided into the following main sections: Forging and stamping techniques; forging and stamping machinery and equipment; heat treatment and heating devices; design of shops; organization and economics of production; technical information; reviews and bibliography; and current events. Much general information of the present state of the industry is contained in the first article.

ABSTRACTS

Standardization and basic trends of technical development in the stamping and forging machine industry from 1959 *to* 1965. YA. K. USPENSKII. Output of stamping and forging machines has risen from 4,700 units in 1940 to 23,000 units in 1957, and this has been accompanied by a corresponding expansion in the number of types of machine in production. Production of the following machines has now been fully developed in the U.S.S.R.: crank-drive forging and stamping presses up to 8,000 tons pressure; hydraulic stamping presses up to 30,000 tons and over; and large cold upsetting machines for the fabrication of bolts and nuts with thread diameters up to 24 mm.; in addition heavy sheet-stamping single- and double-action presses up to 3,500 tons pressure, and automatic sheet-stamping presses with underneath drive and multi-stage automatic machines with pick-up feed up to 250 tons. It is interesting to note that a factor mentioned as retarding the development of cold-upsetting presses is the continued shortage of cold-rolled strip in the U.S.S.R. Many other varieties of stamping and forging machines are also mentioned in this article.

Investigation of the process of metal stamping in closed dies. B. I. ZALESSKII and N. I. TYURIN. The results are set out of research into the filling of the hollow of a closed die and the nature of the distribution of the normal pressure on its wall. On the basis of the results obtained it is possible to determine the most favourable location of the compensator for the excess volume of metal. Experiments were conducted on a 50-ton KhPI hydraulic press, an eccentric 60-ton press and a vertical drop stamp. The following factors were varied: ratio of initial height to initial diameter of the billet from 0·42 to 1·13; the deformation; the ratio of the hollow of the die to the billet diameter from 0·35 to 0·5; angle of inclination of the walls of the hollow of the die and the rate of deformation.

An advanced technique of deep drawing and dies for cylindrical components. M. E. AKSEL'ROD and B. T. BENDETOVICH. Practical examples of deep drawing cylindrical components are discussed, and ways of reducing the number of draws and improving the quality of the components are indicated.

Calculation of press forces during hot stamping of sheet. E. A. SONKIN. Forces calculated by the equations derived showed good agreement with experimental data of the forces set up by the press during stamping.

Problems of designing toggle mechanisms of precision presses. A. F. NISTRATOV. The rigidity of a press and its accuracy in operation are considerably dependent on the rigidity of the toggle mechanism of the crank drive. Apart from this the design of the mechanism affects the rate of operation of the press, frictional losses, the torque on the crank, etc. The theoretical bases for the solution of these design problems are set out in detail.

The question of the choice of the optimum pressure in hydraulic and pneumatic cylinders. B. V. ROZANOV, L. D. GOL'MAN and L. YU. MAKSIMOV. The principles governing the choice of the optimum pressure of such cylinders in relation to the strength of the material, the dimensions of the cylinder and its weight are outlined, and the method of calculating such pressures.

Non-oxidizing heating of steel in open-flame furnaces. V. A. KUROEDOV. Of the various possible methods outlined, heating of steel in open-flame furnaces with high temperature preheat (900°C.) of the primary air in high-efficiency regenerators is selected as the best. After a study of the heat exchange in such regenerators, the design of a regenerator is described, consisting of two perforated cylinders with a checker of metal balls 7·35 mm. dia. providing a heating surface of 457 $m.^2/1\ m.^3$ Each regenerator is designed to be coupled directly to one burner of a furnace, and each of the two burners works alternately. Each combined unit serves alternately as a burner with

continued on page 52

Treatment of a 1% carbon spring steel

Effect of scale removal prior to reheating for quenching

J. W. MEE, A.MET., A.I.M.

An investigation into the effect of descaling prior to reheating for quenching on the decarburization, hardenability and torsional fatigue properties of a carbon steel used for hot-formed springs is described. The author, of the Coil Spring Federation Research Organisation, Doncaster Street, Sheffield 3, also discusses the effect of subsequent shot-peening on the fatigue properties

THERE ARE TWO principal methods of manufacturing hot-formed coil springs, commonly referred to in the spring industry as single or double treatments. In the single treatment the hot-formed spring is withdrawn from the coiling mandrel, its height adjusted and the spring then immediately quenched. If the spring is cooled to room temperature after height adjustment and then reheated for quenching this is known as double treatment.

The temperature of coiling has to be somewhat higher for single treatment than for double treatment in order to allow for heat lost whilst height adjustments are being made, otherwise a low quenching temperature and consequently inefficient quench will ensue. The higher coiling temperature can promote grain growth, decarburization and oxide penetration, all of which will adversely affect the performance of the finished spring. However, points in favour of single treatment are that the hot-scale flakes off during quenching and so does not impair the efficiency of the quench, additionally this process is more economical in labour and equipment.

The double treatment enables a lower coiling temperature to be employed thereby reducing the risk of oxidation, excessive decarburization and grain growth. In addition reheating for quenching ensures a more uniform quenching temperature and produces grain refinement. The drawback is that some of the scale formed during coiling adheres to the spring during air cooling after height adjustment and the presence of this scale during reheating has been shown to considerably increase the depth of decarburization.

Research carried out by Watkinson[1] on laboratory specimens of a number of spring steels showed that for carbon steels the increase in decarburization which resulted from reheating scaled specimens was greatest when the scale had been formed at a temperature higher than the reheating temperature. Scaled specimens which were descaled by pickling produced no noticeable increase in decarburization on reheating. The effect of scale removal on the subsequent decarburization of a 1% carbon steel is clearly illustrated in fig. 1.

It would be expected that the smaller depth of decarburization and the absence of the earlier formed adherent scale, coupled with a much closer control of the quenching temperature, would produce an improvement in the metallurgical structure and the fatigue properties of this spring steel.

A research project carried out at the laboratories of the Coil Spring Federation Research Organisation has investigated the effect of descaling prior to reheating for quenching on the decarburization, hardenability and torsional fatigue properties of a high carbon steel in regular use for the manufacture of hot-formed springs. In addition, the effect of subsequent shot-peening on the fatigue properties of the steel, reheated in both the scaled and descaled condition, was determined.

Experimental procedure

Machined and polished torsional fatigue test pieces were prepared from the same cast of steel used in the earlier work by Watkinson (0·95% C, 0·65% Mn and 0·18% Si). Initial heating at 1,050°C. for 1 hour was selected to provide continuity with this earlier work, although it was recognized that the treatment was more severe than the heating for coiling in normal double treatment practice in industry. On air cooling

from the initial heating temperature, most of the heavy loose scale was shed, leaving behind a thin adherent scale and a surface similar to that of a normal production spring after hot-coiling.

Two methods of descaling were employed prior to reheating, quenching and tempering. The complete schedule of treatment and tests is given in Table I. Fatigue tests in repeated torsion were carried out, the mean stress being half the stress range.

TABLE I *Schedule of treatment and tests*

Descaling prior to reheating	Reheating and quenching	Tempering	Final surface treatment
None ..	850°C. for one hour, oil quenched	435°C. for one hour	None
None ..	,,	,,	Shot-peen‡
Shot-blasting*	,,	,,	None
,,	,,	,,	Shot-peen‡
Pickling† ..	,,	,,	None
,, ..	,,	,,	Shot-peen‡

* Shot-blasting for 15 sec. with No. 24 angular shot at 45 lb./sq. in.
† Pickling in cold 10% sulphuric acid for 2 hours.
‡ Shot-peening at 4 sec./sq. in. with $\frac{1}{32}$ in. dia. chilled iron shot at 30 lb./sq. in. through a $\frac{1}{8}$ in. dia. nozzle, at a distance of 6 in.

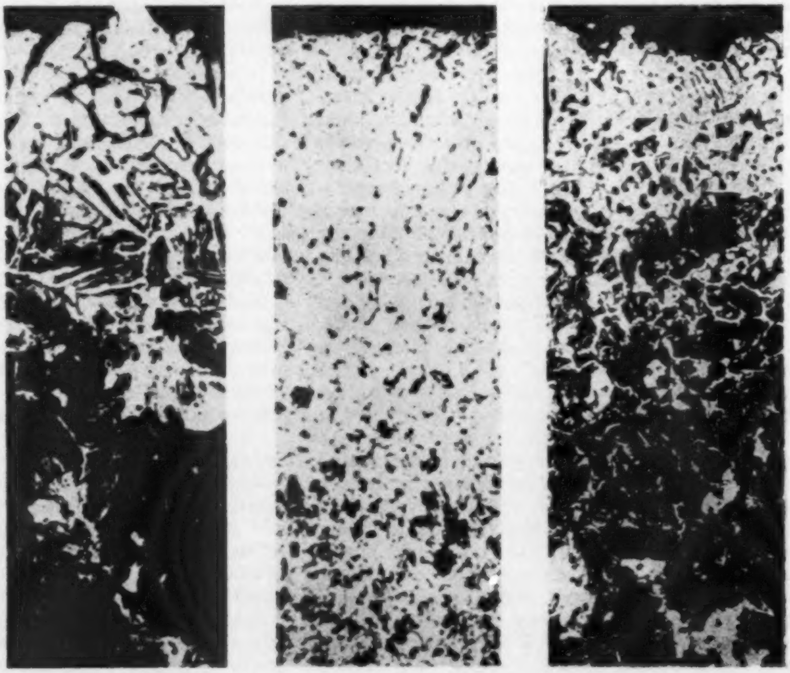
Transverse micro-examination was carried out as near as possible to the origin of failure on at least two test pieces from each series of treatments and a Vickers hardness traverse was determined diametrically across each section. Samples representative of both the scaled and descaled conditions were normalized and micro-examinations carried out to determine the average depth of decarburization of each section as shown in the normalized structure.

Results

The influence of the various types of treatment on fatigue properties is given in figs. 2 and 3. Measurements of hardenability and decarburization are given in Table II and photomicrographs of the metallurgical structures resulting from the treatments are shown in figs. 4 to 9.

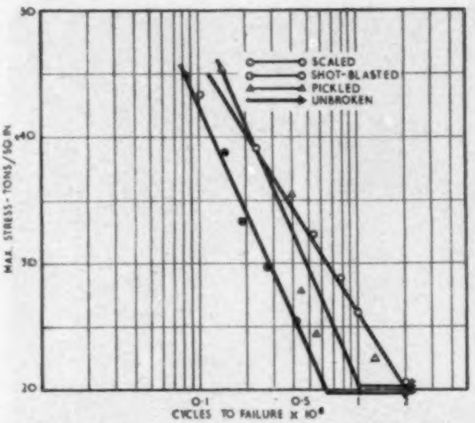
Discussion

The material which had been reheated without prior scale removal contained 50% tempered martensite to a depth varying between 0·05–0·15 in. and was associated with an intermediate transformation product as the distance from the surface increased. Towards the centre of the section the structure changed to pearlite with some free

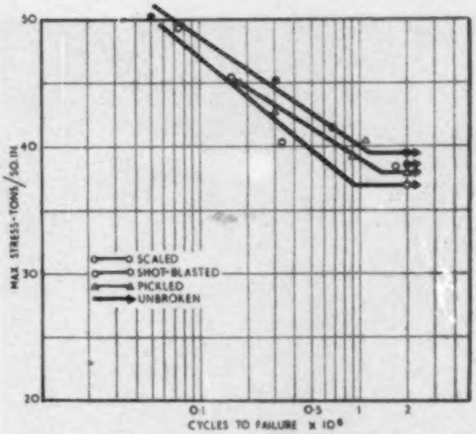


(a) (b) (c)

1 *Decarburization in heavily scaled and pickled* 1% *C steel*
(*a*) *As scaled at* 980°*C.*
(*b*) *Scaled at* 980°*C., reheated at* 850°*C.*
(*c*) *Scaled at* 980°*C., pickled and reheated at* 850°*C.*
× 200



2 *Effect of scale removal on fatigue life without shot-peening*



3 *Effect of scale removal and subsequent shot-peening in fatigue life*

cementite. Fig. 4 shows a photomicrograph of the structure near the surface and fig. 5 that near the centre.

The descaled material contained 50% tempered martensite to depths below the surface varying between 0·10–0·30 in. The structure below the tempered martensite was of an intermediate transformation product which in most instances continued to the centre and in only a few cases was there evidence of a fine grain pearlite with some cementite. A photomicrograph of the rim of tempered martensite is shown in fig. 6 and of the central structure in fig. 7.

Table II *Variations in metallurgical structure with conditions of treatment*

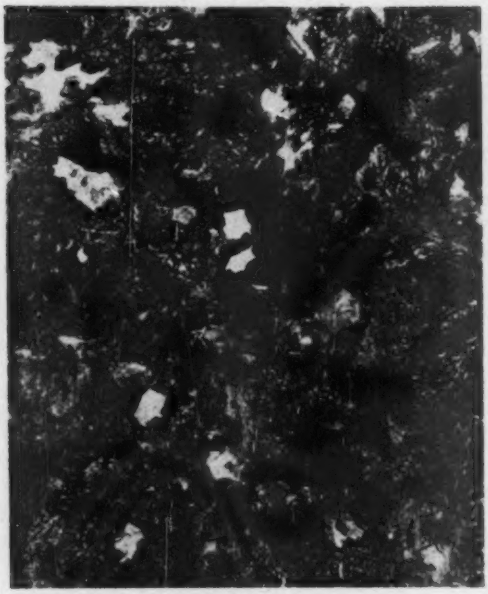
Specimen No.	Method of descaling	Final surface treatment	Depth to 50% martensite (ins.)	Normalized: Total affected depth of decarburization (ins.)	Normalized: Depth to 50% ferrite (ins.)
1	None	None	0·05	0·035	0·020
2	„	„	0·15	0·030	0·012
3	„	Shot-peening	0·11	0·030	0·010
4	„	„	0·07	0·030	0·008
5	Shot-blasting	None	0·17	0·035	0·012
6	„	„	0·30	0·030	0·008
7	„	Shot-peening	0·17	0·030	0·008
8	„	„	0·13	0·025	0·003
9	Pickling	None	0·20	0·035	0·007
10	„	„	0·16	0·030	0·005
11	„	Shot-peening	0·13	0·025	0
12	„	„	0·17	0·030	0·009

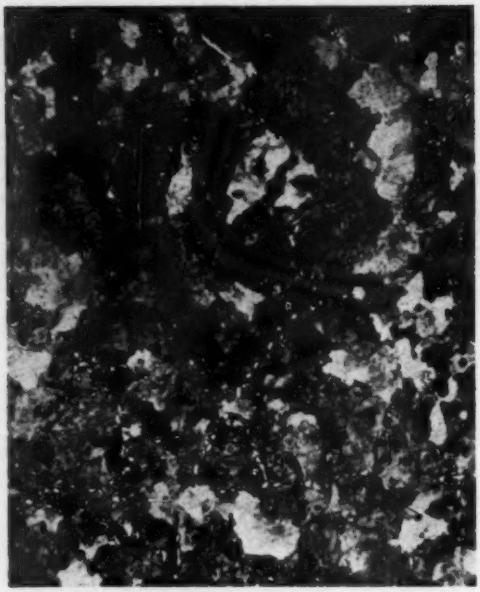
Examination of the normalized material revealed a total depth of decarburization varying from 0·025–0·035 in. regardless of whether descaling prior to reheating for quenching had been carried out. There was, however, a marked difference in the severity of decarburization within this depth, it being more severe in the specimens which had not been descaled. The depth of 50% ferrite in the scaled specimens varied between 0·008 and 0·020 in. and in the descaled specimens between zero and 0·012 in.

There was no clearly defined difference between the hardness of the tempered martensite and the intermediate transformation product, the values ranging from 440–480 V.P.N., but there was a lower hardness, varying between 410–440 V.P.N. in the pearlite zones.

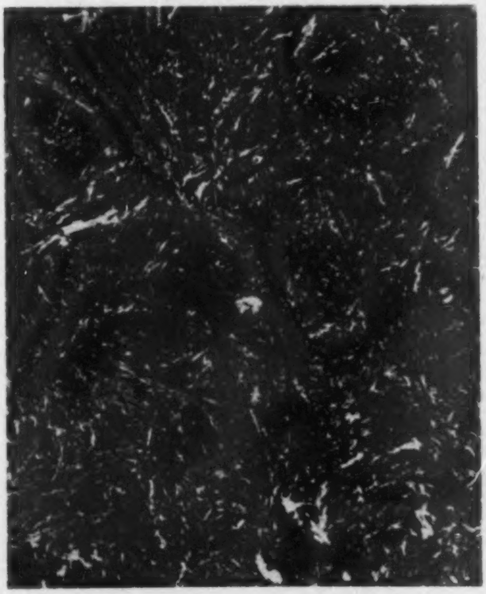
The fatigue results for specimens descaled by pickling showed considerable scatter and this was attributed to stress raisers caused by pickling rather than to hydrogen embrittlement, since any effect due to the latter would have been countered by the subsequent heat treatment. The effect of the descaling treatments was to reduce the fatigue life at stress levels above the fatigue limit without lowering the fatigue limit itself, *i.e.* the curve was moved to the left.

When, however, the specimens were shot-peened the fatigue limit was higher where earlier scale removal had taken place than if the scale had been allowed to remain. The deleterious effects of any stress raisers induced during pickling having been removed, it permitted a more accurate appraisal to be made of the effect of the superior metallurgical structure obtained as a result of the descaling process.

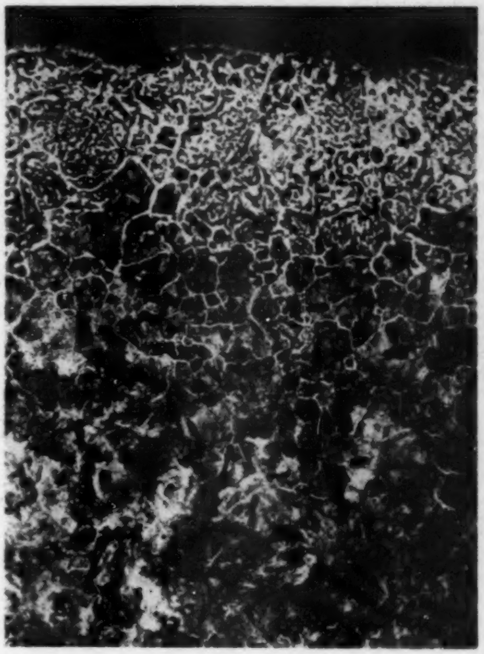


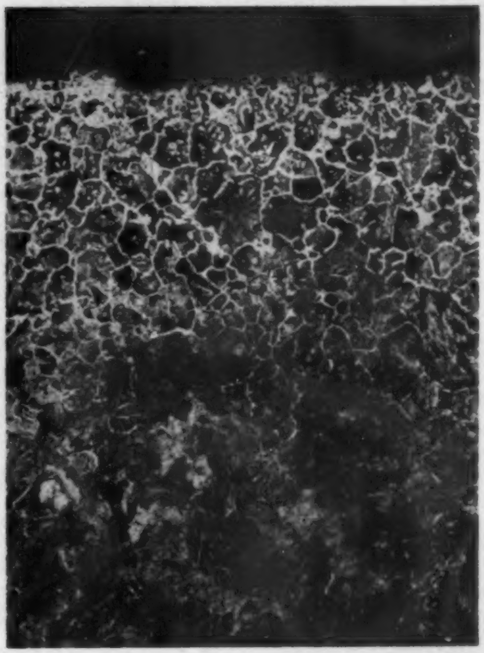


4 and 5 *Hardened and tempered structures—reheated for hardening without prior descaling* (LEFT) *near surface* (RIGHT) *at centre* × 500



6 and 7 *Hardened and tempered structures—reheated for hardening after prior descaling* (LEFT) *near surface* (RIGHT) *at centre* × 500





8 and 9 *Normalized sections showing decarburization* (LEFT) *reheated for hardening without prior descaling* (RIGHT) *reheated for hardening after prior descaling* × 100

Conclusions

Removal of the scale formed by the initial heating before reheating for quenching by use of acid pickling or shot-blasting does not in itself cause an increase in the endurance limit owing to the effect that these treatments have on the surface finish of the material.

As a result of removal of scale before reheating there is a marked decrease in the resultant average depth of decarburization (50% ferrite) from 0·012–0·008 in. and an increase in the average hardenability (50% martensite) from 0·08–0·18 in.

When a subsequent shot-peening treatment is used descaled material has a higher endurance limit than material which has not been descaled. This is due to the effects of reduced decarburization, improved metallurgical structure and removal of stress raisers introduced during descaling.

The overall effect of shot-peening raises the fatigue limit by some 90%, but if the material is additionally descaled prior to reheating for quenching this improvement is raised to 100%.

Acknowledgments

This work was carried out as part of a programme of work initiated by the Research Committee of the Coil Spring Federation Research Organisation. The author wishes to thank Mr. R. Haynes, Director of Research, for helpful discussions and guidance, and Mr. B. Jones who carried out a large part of the experimental work.

Reference

(1) 'Decarburisation of Spring Steels' by J. F. Watkinson, *Coil Spring Journal*, Dec., 1951, (25), 5-17.

Refresher course for older graduates

The Department of Metallurgy, Battersea College of Technology, S.W.11, has organized a number of refresher courses for older graduates to be given at the College during the Easter and summer vacations in the current session. The courses will last three to four days and will be given by members of the College staff and visiting lecturers.

The first courses planned will be as follows: '*The structure of metals and alloys*,' Easter vacation, April, 1960; '*Developments in foundry practice*,' summer vacation, July, 1960; '*Austenite transformation—the present position*,' summer vacation, September, 1960.

The courses are intended for metallurgists who, having completed their academic studies some years ago, may now like to survey the present state of knowledge in fields additional to their own speciality.

Basic research into metal fatigue

An article by Dr. A. J. Kennedy, 'Fatigue since Wöhler' (Eng. Lond. Dec. 12, 1958), *was the starting point of a discussion by a Research Sub-committee of the ASTM. The discussion, which outlined the boundaries of present knowledge of fatigue and suggested further lines of work, was summarized by the chairman, Mr. T. J. Dolan, in the Society's Bulletin, September,* 1959, *on which the following account is based*

WHAT IS BASIC to the designer is on an entirely different level of inference and observation from what is basic to a research engineer, which in turn may be different from what is basic to a scientist. Thus, one must recognize different levels of research with a mutual interchange of knowledge and a feedback of new information, techniques, and problems of interest. Within this type of framework there are many levels of investigation that can be suggested as having merit and possible future application to engineering analysis of the fatigue problem.

Fatigue failure is merely one manifestation of the behaviour of crystalline solids under stress, and only by studying all possible aspects of this behaviour can one hope to make real progress in knowledge of the phenomena. It must be understood by those who undertake studies in this field that they cannot just walk into a laboratory and at once make an important fundamental discovery. However, by concentrated and intelligent application of new research techniques they should be able to shed additional light upon the instabilities, micro-readjustments, surface behaviour, or other aspects of the reaction of crystalline solids to repeated stressing. This presupposes, of course, that the investigator is competent, sincere, alert, and that he carefully plans and analyses every step in his investigational and interpretative procedures.

Additional knowledge of fatigue needed

There are perhaps two distinct areas or levels of observation at which additional work needs to be done to improve knowledge of the fatigue phenomenon: (1) Basic studies are needed to shed additional light upon the occurrences within the space lattice at the atomic level, and (2) studies on the phenomenological or engineering level need to be correlated with these 'basic' studies to clarify the relationships between ageing, cold work, heat treatment, fatigue strength, and fatigue life. The desired end-result, of course, is a set of quantitative relations with which can be predicted the influence of manufacturing and fabrication processes. From the engineering viewpoint it appears that the complexity of the fatigue phenomenon can be traced to the fact that progressive fracture is a sequence of at least two phenomena—(1) the initiation and (2) the propagation of cracks—which may be governed by two different sets of criteria. Designers are confronted with the problem of appraising the influence of notches, mean stress, cumulative damage, etc., which may not be the same during crack formation and during crack propagation. Many past investigations have obtained values for fatigue limit or fatigue life for a specific type of specimen under a given condition of stressing and environment. Though thousands of such tests have been made, the results cannot readily be interpreted in terms of general behaviour of materials or carried over into the design of actual metal products. This is merely further evidence of a need for more complete knowledge of the fundamental behaviour that can be applied to many classes of materials for a wide variety of environmental conditions.

The experimenter, whether he is concerned with fundamental or with applied research, must design his experiment to ask the right question in the right way of his test specimens and planned observations. Thus he becomes the responsible quiz master who must attempt to state the problem in a specific manner so that the data will have meaning. Suggestions for research must not hamper his creativeness nor limit his areas of inquiry. The suggestions presented here are intended rather to outline general broad problems of specific concern at the present time and to suggest some of the types of research tools which now seem to offer avenues along which bright young investigators might travel in seeking a better understanding of the many parameters and variables and the manner in which these influence fatigue.

In general, the engineer looks at the problem from the viewpoint of obtaining more concise ideas of the relation between such items as damping and fatigue damage, phenomena occurring above the knee of the *S-N* curve as compared to those below, the relationships between coarse slip and fine slip, influence of atmospheric and chemical corrosion in combination with fatigue, studies of notches, mean stress, effects of overstrain, etc. These worthy

areas of investigation require new techniques or unusual methods of approach to obtain any significant new contributions. It appears that the most promising lines of attack are those recently developed by the metallurgists and physicists involving basic studies of mechanisms on a micro-scale, such as surface phenomena or the contributions made by instabilities of structure, diffusion of foreign elements in the structure, etc. This means that the best approach to a basic understanding of fatigue consists in making a study of those physical factors which change in a metal as a result of fatigue cycling.

The following items are suggested in a general way as representative of some factors about which information is lacking. The most important of these factors appear to be interaction between interstitial atoms or foreign atoms and dislocations. For steels, the changes in carbon position and form and changes in the stress state are examples of the instabilities and interference effects that occur in metals. All of these need to be correlated and their mechanisms observed as fatigue cycling proceeds. The over-all criterion will remain the influence of these micro-mechanisms on the 'large-scale' or over-all fatigue behaviour of a specimen or machine component.

Etching techniques and dislocations

Considerable effort has already been expended in many laboratories in developing etching techniques that will produce pits indicating the position of static dislocation. This technique opens up the possibility of studying the response of individual dislocations to cyclic stressing. The hypothesis that initiation of a micro-crack is the result of stress concentration from the pile-up of dislocations—on the same slip plane—at a barrier may become capable of exprimental proof. Probably such studies could be made of simple materials of large grain size. Another hypothesis that might be studied suggests that a crack may form and grow on each loading cycle by being fed by dislocations moving in from the surrounding lattice.

The possibility of using transmission techniques on thin films of metal in the electron microscope has been suggested. Such an application permits the observation of dynamic phenomena, but in a way that is more difficult to interpret than with the etch pit technique alone. Future developments of new methods and reproducible techniques of observation and measurement might be possible. The Berg-Barrett method of X-ray diffraction also gives promise of being a tool to determine instantaneous dislocation position. This would then allow the correlation of cyclic stressing and change of position as already noted.

Accumulation of vacancies

Another theory indicates the possibility that fatigue crack initiation or propagation may be simply the accumulation of lattice vacancies. Low-temperature data indicate the presence of fatigue even in the absence of thermally induced diffusion through the lattice. The driving force for the movement or accumulation of vacancies is undoubtedly the externally applied stress field. The experimental techniques for examining vacancy accumulations are not so well developed as those for studying dislocation movements. One method that has been used is small-angle scattering of X-rays. A second method that has received less attention is cold-neutral irradiation. The use of these techniques in fatigued material has indicated that growth of clusters of vacancies accompanies increasing cycles of stressing. It is appreciated that vacancy accumulation is probably very intimately tied in with dislocation motion. The intersection of moving dislocations may be the principal cause of the formation of vacancies. Therefore a study of dislocations will yield information on the nucleation of fatigue damage.

Instabilities: interaction with interstitial atoms

Previous work has indicated that cyclic stressing will precipitate the carbon originally in solid solution into other forms, such as iron carbide. It also seems that such precipitation occurs in the slip lines—the area that eventually becomes the nucleus of the fatigue crack. That such precipitation helps to retard fatigue damage may yet be a point to be established for some of the complex metals and alloys. Precipitation phenomena can be examined and monitored by the use of the high magnification provided by the electron microscope. Determination of internal friction damping is another method that should give some indication of the accumulation of interstitial atoms or precipitates. Much credence is given the belief that there are stress interrelationships between dislocations and carbon atmospheres. Thus the changing position of the carbon with stress becomes at least a secondary factor in its possible influence on dislocation phenomena. These effects are not restricted to carbon in iron or to ageing effects in body-centred cubic metals, but apply also to nitrogen, oxygen, etc., in a number of metals. In general, they may occur in any alloy for which there is a large change in solubility so that a second phase can be precipitated into the primary phase as in aluminium alloys.

Stress state and environment

It is conceivable that structural alterations caused by dislocations, vacancies, or precipitate

changes might be reflected in changes in the stress state of the material, particularly on the atomic level. Such changes might conceivably be studied by the microstress method based upon the distortion broadening of the X-ray diffraction-line profile. Macro-residual stress almost undoubtedly influences fatigue crack propagation and would probably best be studied by the use of measuring techniques based on X-ray diffraction.

The fatigue lives of some metals are apparently markedly affected by oxygen in the atmosphere or by changes in relative humidity. Studies of the surface chemistry, including the nature and behaviour of surface films and of diffusion of foreign atoms into the surface layers, might be fruitful. Since the mechanisms of chemical attack and diffusion are sensitive to the effects of time and temperature, these latter parameters should be given careful consideration to determine their relative contribution to the behaviour of materials under repeated stress.

Microplasticity analyses

It has been observed on a micro scale the development of slip-band striations and the nucleation of cracks around intrusions and extrusions in metals under cyclic conditions. Though some explanations for these phenomena have been offered in terms of dislocation movements, more experimental and analytical study of the mechanism on the micro scale should be fruitful. These and other phenomena of fatigue may also be studied at a 'micro' level by regarding the behaviour of an individual crystal in a polycrystalline structure as a phenomenological problem in much the same manner that one would study the strength and deformation of members of large size such as a thick-walled tube under internal or external pressure. That is, a sufficiently large number of atoms may be considered as a continuum and the principles of elasticity and plasticity applied to predict the behaviour of the crystal as affected by its interaction with its neighbours in the structure. It may be possible to formulate at this level of structure a set of laws for yielding and fracture much in the same manner as has been done for larger-scale polycrystalline structures.

Recapitulation and conclusion

Many of the foregoing suggestions border on studies closely related to solid state physics; perhaps the results of much of the research suggested would not appreciably change what can be done in the immediate future at the engineering level. There is no assurance that a knowledge of the atomic mechanism of fatigue crack initiation and propagation will make any radical change in what can be done about raising the fatigue strength of a member, such as a turbine blade, for example. Before useful applications can be obtained, the scientists working at the atomic level must attempt to bring their understanding of the structure and its relationship to properties up to the level of the 'micro scale,' where there could be a common interest with the engineer and metallurgist and a mutual transfer of information that would prove of benefit to both groups.

A possible logical outcome of such a programme would be that one of the variables mentioned in the foregoing or some combination of them would be found to correlate directly with the fatigue process, thus indicating its quantitative importance in the resulting initiation or propagation of the fatigue crack. With such a story documented, it would seem logical that the next step would be 'development research'—that is, attempts to control a sensitive variable or variables through compositional or processing influences.

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hot air delivery and as a flue for final combustion and extraction of the combustion products. Mixing in both directions is good through a combination between an injection mixer and a Venturi-tube type mixer, setting up little resistance. The experimental furnace proved satisfactory in operation; at a gas consumption of 50 m.^{3}/h. and an excess air coefficient of 0·4 the temperature of the working zone varied between 1,230 and 1,250°C. The mean temperature of the combustion products in front of the regenerator was about 1,000°C.; with a checker thickness of 70 mm. the primary air temperature was about 900°C.

The productivity of automatic machines and automatic production lines through the co-ordination of operations outside the production cycle. N. N. Shevyakov. Problems of production quality and quantity are related to the productivity of reorganized shops and sections, and the utilization of equipment and economic considerations are discussed.

Forging and stamping equipment abroad. V. A. Babenko. A general review is given of such equipment, and the present design trends are outlined.

A new design of consecutive dies for multiple stamping of rectangular components. V. I. Barbot.

A simplified method of determination of the dimensions of blanking dies. D. A. Vaintraub.

New dies for bending components from steel angles. A. I. Markhula.

Hot die calibration instead of machining. B. D. Kopyskii.

Mn-V steel for large forgings

R. ŠEJNOHA

Tests have been carried out on large forgings in manganese-vanadium steel to study the effect of vanadium content on mechanical properties and the effect of heat treatment on microstructure. The work was aimed at finding out the causes of cracking in the segregation areas of forgings in this alloy, and was reported by the author, of Klement Gottwald Steelworks, Ostrava-Kuncice, in ' Hutnické Listy,' 1959, (8)

FOR LARGE FORGINGS, steels alloyed with vanadium are frequently used. This is done, on the one hand, in those instances where reliability of the mechanical properties at high temperatures is demanded and, on the other hand, when the maintenance of homogeneous and fine grain is required. In forgings in these steels, however, from time to time faults occur which are commonly known as ' cracks in the segregation areas.' This refers to fine cracks concentrated in the top end of a forging (hereafter referred to as end *A* of a forging) in the V-segregate zone, and normally attributed to the adverse effect of sulphur inclusions. This work is concerned with cracks of this type which formed in several instances during the production of a large number of separator forgings in manganese-vanadium steel.

Method of production

In fig. 1 is a drawing of the separator forging. The ingot used had a weight of 43 tons and the mean diameter of the body was 1,400 mm. The ingots were cast in steel to specification CSN 13 123, which contains 0·23% C, 1·10% Mn and 0·20% V. In certain instances the steel is produced in a basic open-hearth furnace, and in others in an electric furnace.

The separators were forged as solid bodies of 25 tons in weight (fig. 1 (*a*)) with three intermediate heating periods. As the second operation in the forging process, upset forging was carried out to a diameter of 2,100 mm. The degree of forging, expressed as the ratio of the cross-sectional areas, $K = A_1/A_2$ (where for the cast state correspondingly $K = 1$), amounts for the forging of the stock to 2·5 in the flange, and to 5·5 in the body, of the separator.

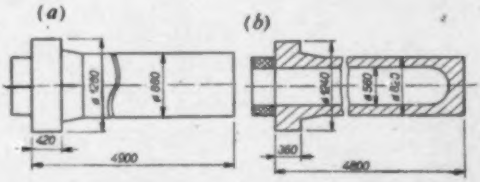
The forging temperatures lay within the limits set by the specification. The flange section of the separator was located in end *A* of the ingot. Test-pieces were taken from end *A* from an additional piece forged on to the flange, the diameter of which was equal to the diameter of the body of the separator. Apart from this test-pieces were taken from the body of the separator at the bottom end of the ingot (hereafter referred to as end *Z*).

After forging was completed, the forging was charged into a furnace, cooled to 720°C., annealed and again cooled in the furnace at a rate of 0·25°C./min. down to 200°C. After rough boring (fig. 1 (*b*)) the actual heat treatment was carried out, which consisted of normalization (austenitization temperature 900°C.) and tempering.

The average chemical composition and the average values of the mechanical properties of the forgings are shown in Table I. The low content of P and S was maintained in both the open-hearth and electric furnace melts. The strength properties are somewhat lower at end *A*, but the important difference between ends *A* and *Z* lies in the values for the reduction in area, which in certain instances were unacceptably low at end *A*.

A determination was made of the average chemical composition of the forgings with unacceptable values for the reduction in area; no difference was found in the content of all the elements with the exception of vanadium, by comparison with the values shown in Table I. The vanadium content amounted to 0·20%, that is to say considerably higher than the mean value shown in Table I.

Experiments were therefore conducted to deter-

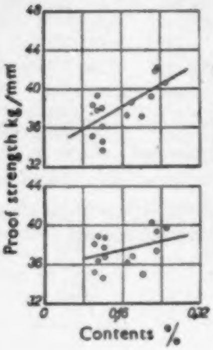


1 *Sketch of the separator forging: (a) rough forging; (b) forging after rough boring*

2 *Effect of the vanadium content on the proof stress of the separators, with a correction for the effect of C, Mn and Si.* TOP *End Z;* BELOW *End* A *(mean values)*

3 *Effect of the vanadium content on the tensile strength of the separators, with correction for the effect of C, Mn and Si.* TOP *End Z;* BELOW *End* A *(mean values)*

4 *Effect of the vanadium content on the reduction in area of the separators.* TOP *End Z;* MIDDLE *End* A *(mean values);* BELOW *End* A *(minimum values)*



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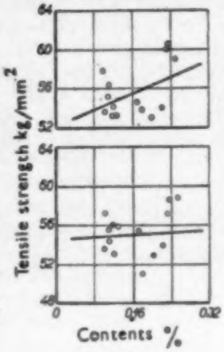

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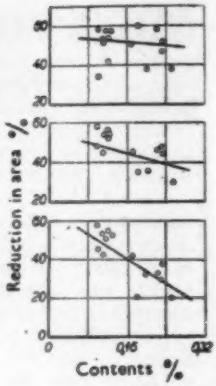

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TABLE I *Average chemical composition and mechanical properties of the separators*

Chemical composition: 0·21% C, 1·16% Mn, 0·31% Si, 0·11% Cr, 0·15% V, 0·020% P, 0·020% S

	End *A*	End *Z*
Proof stress, kg./mm.²	37·5	38·0
Tensile strength, kg./mm.².. ..	55·2	55·6
Elongation (1 = 5d), %	23·3	24·8
Reduction in area, %	45·0	50·1
Notch impact strength, kg./cm.²	11·8	11·1

mine the influence of the vanadium content on the most important mechanical properties: proof stress, tensile strength and reduction in area. The result is contained in the diagrams in figs. 2–4, shown separately for ends *A* and *Z*. The proof stress and tensile strength values were corrected in respect of the contents of C, Mn and Si (the coefficients were: C + 25 kg./mm.²/%, Mn and Si + 8 kg./mm.²/% for the proof stress; C + 60 kg./mm.²/%, Mn and Si + 10 kg./mm.²/% for the tensile strength[1]). In the diagrams in general the mean values are given; in addition to this, for the reduction in area of end *A* the effect of the vanadium content on the minimum values is also shown. The influence of vanadium is also collated in Table II; at end *A* vanadium raises the proof stress and especially the tensile strength less than at end *Z*. The reduction in area is only little influenced by vanadium at end *Z*, while at end *A* it is markedly reduced thereby.

TABLE II *Effect of vanadium on the mechanical properties of the separators*

	Change in the value on increasing the vanadium content by 0·1%	
	End *Z*	End *A*
Proof stress, kg./mm.² ..	+ 2·8	+ 1·2
Tensile strength, kg./mm.²	+ 2·2	+ 0·3
Reduction in area, % ..	− 2·0	− 7·0 (− 16·0)

The value shown in brackets for end *A* indicates the coefficient for the minimum reduction in area of end *A*.

The distribution of the sulphides is shown in the Baumann print in fig. 5; this is taken from the vicinity of the internal surface of the wall of the rough bored separator at end *A*, *i.e.* in the area which produced the worst Baumann prints. The shape, size, distribution and quantity of the non-metallic inclusions corresponded to the ingot used.

The hydrogen content was in all instances small, and varied around 4 cm.³/100 g. In the forgings with low values for the plastic properties at end *A*, the hydrogen content did not differ from the mean value. This particular type of steel has no tendency to the formation of flakes. In general, however, the suggestion has been put forward that vanadium lowers the tendency towards flake formation.[2]

The microstructure of the forgings was marked by extreme inhomogeneity, which was very much greater at end *A* than at end *Z*. Fig. 6 shows an overall picture of the microstructure of end *A* in a tangential direction. On this micrograph may be seen fine-grain network structures of mixed ferrite and pearlite, which surround the coarse-grained part of the structure; this is built up from accumulations of grains of ferrite and segregated pearlite, and the pearlite is distributed between the grains of ferrite in an unusual form of lines and network structures. Figs. 7 (*a*) to 7 (*c*) show these individual types of microstructure at higher magnification. In a longitudinal direction the inhomogeneity of the structure was manifest in the form of parallel strips. The structural inhomogeneity is connected simultaneously with chemical inhomogeneity. This is apparent in the varying proportion of pearlite in the individual zones of the structure (varying carbon concentrations), and likewise by the varying degree

of hardening, which was found to exist after quenching a separator from 900°C. in water (fig. 8). This is evidence of the uneven distribution of the elements which increase hardenability.

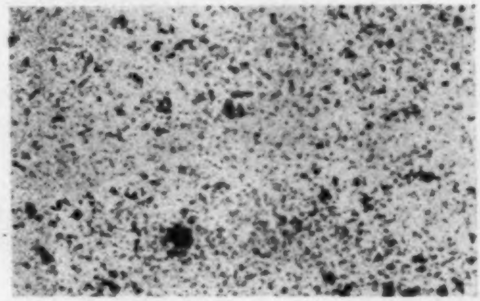
From the facts presented it may be judged that the inhomogeneity of the microstructure and that of the chemical composition, which are connected with the dendritic nature of the solidification of the ingot and with its primary structure, were maintained even in the finished forging. In fig. 6 the boundaries of the primary grains have been delineated; they run through the fine-grain part of the microstructure.

In forgings with the lowest values for the reduction in area cracks were found in the material for test-pieces at end *A* and over the whole of the flange, such as are shown in figs. 9 (*a*) and (*b*). The cracks were concentrated in the region of the V-segregate, as is partially shown by fig. 5. But in the great majority of instances the fracture surface consisted simply of microscopic foreign inclusions. Sulphides were present on it only in certain instances. After etching it was established that the cracks ran through the fine-grain part of the microstructure, *i.e.* in the area of the primary grain boundaries.

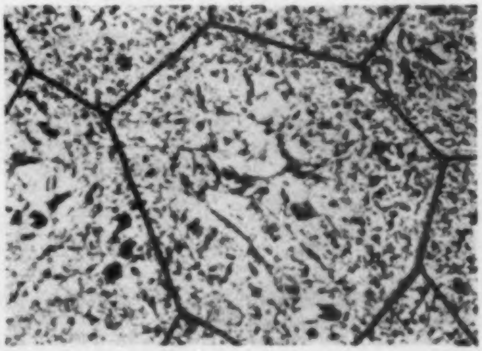
The effect of heat treatment on the microstructure

From the segment, of which the microstructure is shown in fig. 6, samples were taken of dimensions 8 × 15 mm.; of these, one was austenitized at 900°C. for 1 h. and quenched in oil and the other was austenitized at 900°C. for 1 h. and cooled in air (cooling rate at 700°C., 80–100°C./min.). The hardened specimen had a normal martensitic structure. The structure of the normalized specimen is shown in fig. 10; it is an extremely fine-grain microstructure, the particle size distribution is not widely divergent, and the abnormal distribution of pearlite which was shown in fig. 6 has completely vanished. Nevertheless, the distribution of carbon is not even at greater distances apart; the strips with a higher concentration of pearlite in fig. 10 (*a*) are evidence of this.

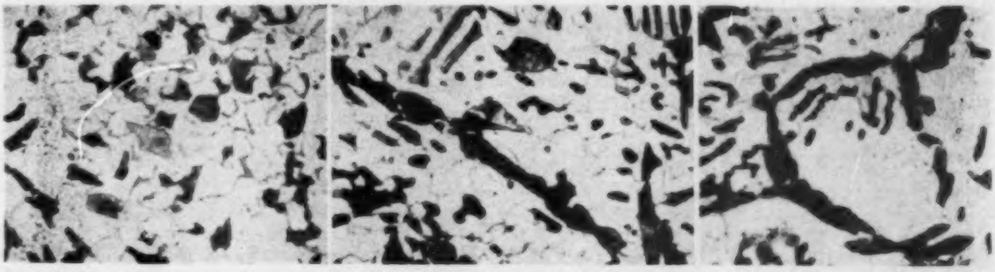
5 *Distribution of sulphides as shown by a Baumann print*



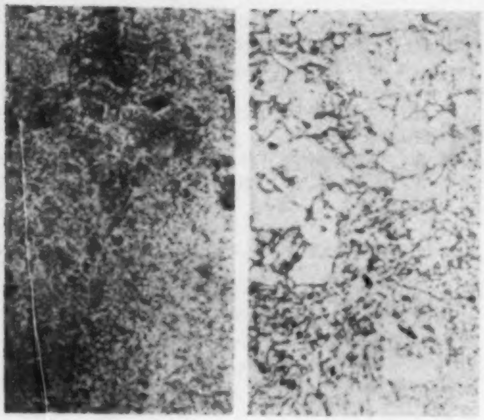
6 *General view of the microstructure of a normalized forging with the primary grain boundaries delineated*



7 *Types of microstructure of the separators after normalization: (a) fine-grain part of the microstructure; (b) continuous bands of pearlite in the coarse-grain part of the structure; (c) networks of pearlite in the coarse-grain part of the structure.* HNO_3. × 250

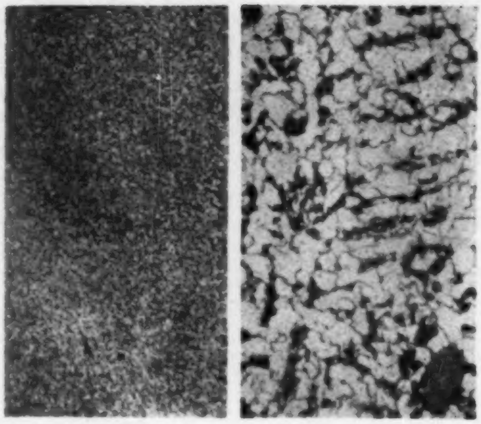


7 (*a*) 7 (*b*) 7 (*c*)



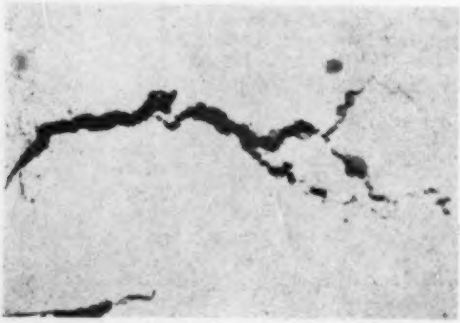
8 (*a*) 8 (*b*)

8 *Microstructure of a separator after quenching in water from 900°C. HNO_3. (a) × 50; (b) × 500*

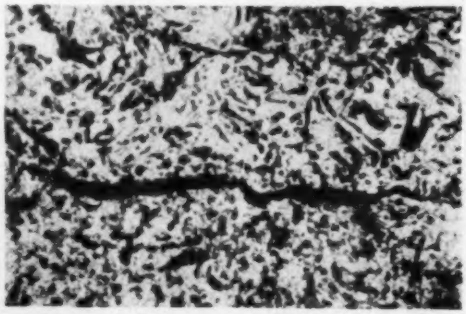


10 (*a*) 10 (*b*)

10 *Microstructure of a specimen from a separator forging after normalization (cooling rate at 700°C. about 80–100°C./min.). HNO_3. (a) × 50; (b) × 500*

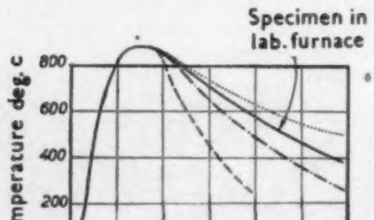


9 (*a*)

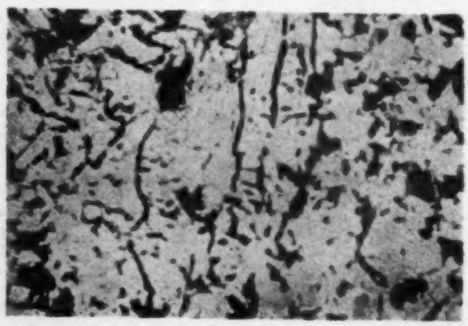


9 (*b*)

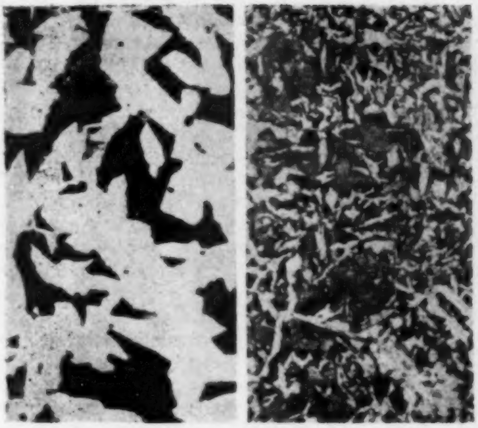
9 *Appearance of the cracks. (a) N. (b) HNO_3.* × 100



11 *Cooling of the specimens in the laboratory furnace*
– – – – boiler body, dia. 1,200 mm., wall thickness 160 mm.
–.–. solid cylinder, dia. 900 mm.
. . . . solid cylinder, dia. 1,250 mm.

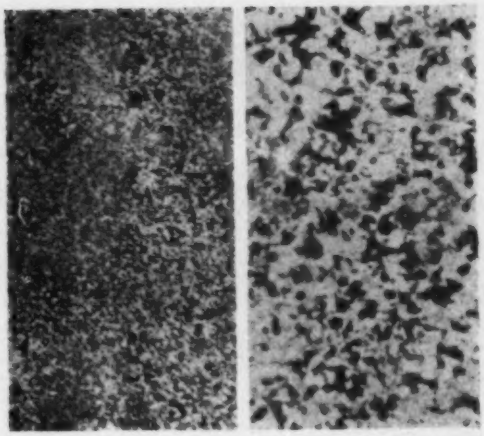


12 *The normalized specimen shown in* **10** *(a), after renewed austenitization and cooling in the furnace (cooling rate at 700°C., 0·5°C./min.). HNO_3.* × 100



13 (a) 13 (b)

13 *Microstructure after homogenizing heat treatment at 1,100°C. for 6 h.: (a) after heating the specimen was cooled in the furnace at a rate of 3–5°C./min. to 600°C.; (b) after heating the specimen was cooled in the furnace at a rate of 0·25°C./min. to 600°C. HNO_3.* × 50



14 (a) 14 (b)

14 *Microstructure after homogenizing heat treatment at 1,100°C. for 6 h., cooling in the furnace to 600°C. at a rate of 3–5°C./min.: (a) and 0·25°C./min.; (b) with renewed austenitization at 900°C. and cooling in the furnace (cooling rate at 700°C., 0·5°C./min.). HNO_3.* × 50

Both the specimens, the quenched and the normalized, were once again austenitized at 900°C. for 1 h. and cooled in the furnace (cooling rate at 700°C., 0·5°C./min.). The sequence of this heat treatment is shown in fig. 11, in which for comparison are also shown the cooling curves of a boiler body of similar dimensions to those of the rough bored separator, and of two solid forgings. The specimens in the furnace were thus cooled even more slowly than the rough bored separator forging during normalization, where the cooling rate at 700°C. amounted to 1·5–2·0°C./min.

After this heat treatment once again a heterogeneous microstructure of the same type as that shown in fig. 6 was formed in both the specimens. Fig. 12 shows the microstructure of the specimen which was previously normalized, the microstructure of which after normalization was shown in fig. 10.

Further specimens of the segment were homogenized by heating at 1,100°C. for 6 h. and cooling in the furnace. Cooling in the furnace between 1,100 and 600°C. took place, on the one hand, at a rate of 3–5°C./min., which is the natural cooling rate of the small laboratory furnace, and, on the other hand, at a rate of 0·25°C./min. The low cooling rate, which was obtained by decreasing the heating output of the furnace, corresponded to the cooling of a large forging in a furnace.

The homogenized specimens were austenitized at 900°C. for 1 h. and cooled in the furnace in accordance with the diagram in fig. 11. The cooling rate at 700°C. was 0·5°C./min.

The microstructure of the specimens after homogenizing heat treatment is shown in fig. 13. In the specimen which was cooled more rapidly from 1,100°C. ferrite is precipitated more finely in the form of acicular and sagittate crystals. After gradual cooling the grains of ferrite are massive, while the Widmannstätten sagittate crystals are only precipitated in exceptional instances.

After austenitization at 900°C. for 1 h. and cooling in the furnace, the resultant structure is formed of an abnormal precipitation of pearlite, especially in the specimen which was cooled more rapidly from 1,100°C. The distribution at a greater distance apart, however, still remained heterogeneous (fig. 14 (a)).

The nature of the formation of this inhomogeneity of the structure, characterized by the network and strips of pearlite, was studied on small specimens which were austenitized at 900° C. for 1 h. and cooled in the furnace in accordance with the curve in fig. 11, and then quenched in water + 10% NaOH from various temperatures from 900 down to 690°C. A transformation took place within the range of temperatures from 780–690°C. Nuclei of ferrite formed first of all in vacancies in the austenite located about 1 mm. apart; from these nuclei grew the accumulations of grains of ferrite, which forced out the austenite into the network structures; in these structures pearlite finally formed. In the vacancies between these areas nuclei of ferrite formed at a lower temperature, and the structure

under investigation then contained a greater proportion of pearlite.

All the specimens were sealed into quartz tubes for the heat treatment, so that they were protected from any form of oxidation or decarburization.

Assessment

In the finished forgings after heat treatment there was found to be inhomogeneity of the structure, dependent upon the inhomogeneity of the ingot and the dendritic nature of its solidification. One of the phenomena of this inhomogeneity is variation in the concentration of carbon and of the elements which increase the hardenability, and at the same time the differing particles size of the grains in the solid solution, namely vanadium and probably also manganese, in areas varying around 1 mm. in extent, *i.e.* proportional to the primary grain size. The fine-grain network sections of the structure with a high proportion of pearlite show that the distribution of this structure corresponds to the primary grain boundaries. The second type of inhomogeneity in the structure under study is the separation of pearlite into strips and network structures in internal sections of the primary grains.

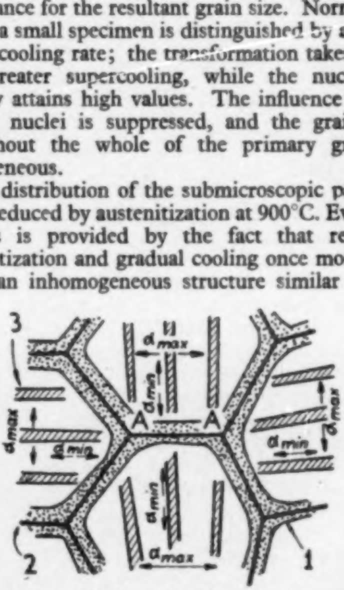
The appreciable difference in grain size in the network on the boundaries of the primary grains and within these grains cannot be explained by the different degree of rate of nucleation and rate of growth as a result of different cooling and different chemical composition of the individual sections of the primary grain, for at a very low cooling rate supercooling is in general at a minimum, and secondly the chemical composition influences the rate of nucleation and growth in the same sense, and therefore differences in the composition will have relatively little influence on the resultant grain size.[3] A very much greater influence on differences in the grain size is exerted by the structural inhomogeneity, which affects the rate of nucleation and, to some extent, the rate of growth by being structurally unresponsive.[4] The fundamental difference in the grain size of the boundaries of the primary grains and their interiors may more readily be explained by the presence of sub-microscopic particles on the boundaries of the primary grains which function as the nuclei of foreign phases during the breakdown of austenite.

An increased concentration of similar particles is manifested on the boundaries of the primary grains in instances where particles with a high melting point occur, which are present during the freezing of the steel in an already solidified form and accumulate in those parts of the melt which are the last to solidify. It is known that Al_2O_3 and vanadium compounds behave in this manner in insufficiently hot melts.[2] Enrichment of the boundaries of the primary grains in such particles takes place likewise in those instances where a substance with low solubility in austenite occurs which is precipitated from the solid solution at high temperatures. It is also known that sulphur behaves in a similar manner; an excess of it is precipitated from austenite at high temperatures in the form of sulphides.[5]

The quantity of sub-microscopic particles, whether they be present for the first or the second reason, as a result of the manner in which the ingot solidifies, is greater at the top end than at the bottom end, and this is especially true precisely on the boundaries of the primary grains, where in an extreme instance they form into a film which weakens the cohesion of the grains. There is a drop in the malleability, especially of the reduction in area, a fall in the tensile strength values is apparent, and premature fractures occur, which run partly or entirely along the boundaries of the primary grains. Fractures of this type take place in the cast state. The tendency towards their occurrence is reduced by working.

During the normalization of a large forging the cooling rate of the austenite is low; the transformation takes place with inconsiderable supercooling, while the number of indigenous nuclei is low; foreign nuclei therefore have a predominant importance for the resultant grain size. Normalization of a small specimen is distinguished by a much higher cooling rate; the transformation takes place with greater supercooling, while the nucleation velocity attains high values. The influence of the foreign nuclei is suppressed, and the grain size throughout the whole of the primary grain is homogeneous.

The distribution of the submicroscopic particles is not reduced by austenitization at 900°C. Evidence of this is provided by the fact that repeated austenitization and gradual cooling once more produces an inhomogeneous structure similar to the



15 *Illustration of the formation of structural stresses on the boundaries of the primary grains*
1 *fine-grain structure on the boundaries of the primary grains*
2 *primary grain boundaries*
3 *strips of pearlite in the coarse-grain part of the structure*

initial structure. It is only by austenitization at 1,100°C. that a change occurs in the distribution or coagulation of these particles and a lasting removal of their influence. The great divergence in the particle size of the areas along the grain boundaries disappears. The abnormal distribution of the pearlite in the internal part of the primary grain completely vanishes.

The dendritic inhomogeneity, which is characterized by alternate zones with a high and low content of pearlite at distances of about 1 mm. apart, noticeably has a very considerable stability; it was preserved not only after upsetting and forging of a separator with a forging coefficient of 5·5, but even after homogenizing heat treatment at 1,100°C.

The effect of vanadium on the deterioration in the plastic properties, such as has been described in this work, was also found in other types of large forgings, even if it was not in such a striking form.[6] From this it is possible to deduce that in forgings where the degree of working is substantially less than that of normal rolled material unfortunate attendant phenomena become apparent which are connected with the vanadium content, and these are difficult to overcome during the production of the steel. These are:

1. An increase in the degree of dendritic inhomogeneity in the cast state, and at the same time an increase in its stability during working and heating.

2. Weakening of the cohesion of the primary grain boundaries, which may be due to the direct or the indirect action of vanadium. Under the direct action may be included the influence of the microscopic particles of the vanadium compounds concentrated in the area of the boundaries of the primary grains; these compounds have very low solubility in austenite. Indirectly vanadium can, for instance, exert a similar influence to that of aluminium in increasing the solubility of sulphur in austenite at high temperatures, which has the consequence of precipitating sulphides on the boundaries of the primary grains during cooling.[5]

The use of a larger quantity of vanadium for large forgings cannot therefore be recommended. It is expedient to restrict its content to as small a quantity as possible, or replace it by another element, Ti or Mo, for instance.

During heating of the structure in accordance with fig. 6, apart from normal thermal and transformation dilatations, considerable structural expansions also occur, which are the result of the different coefficients of thermal expansion of the phases which are present (Table III). The coefficient of thermal expansion of the area of the primary grain boundaries is determined by the average quantity of ferrite and pearlite. In the internal part of the primary grains there is shown to be a high tensile strength of the pearlitic network; in certain directions the actual thermal expansion will correspond to the coefficient of pearlite, *i.e.* will have a low value, and in this direction the ferrite will be plastically deformed by compression; in other directions, however, the coefficient of thermal expansion must be high. Fig. 15 represents an arrangement of the primary grains, whereby on the boundary A–A tensile structural dilatation occurs.

TABLE III *Comparison of the thermal expansion and hardness of the phases of normalized carbon steel*

	Ferrite	Cementite	Lamellar pearlite
Linear coefficient of thermal expansion at 20–100°C. in mm./mm./°C.	(12–12·5) × 10^{-6}	(6–6·5) × 10^{-6}	(10–11) × 10^{-6}
Vickers hardness at 20°C... ..	60	about 1,000	200

Conclusions

In a very large number of large forgings in manganese-vanadium structural steel the author found a close relationship between the vanadium content and the deterioration in the plastic properties of that part of the forging from the top end of the ingot. A marked dendritic inhomogeneity of the ingot was also found, and stability of this inhomogeneity during the working and heat treatment of the forgings. Likewise it was established that weakening of the cohesion of the boundaries of the primary grains took place.

The author is of the opinion that for large forgings, in which the degree of forging cannot attain considerable values, the use of steel containing vanadium is unsuitable, since during the production of this steel it is only possible with great difficulty to prevent the faults which have been described. He recommends that for such purposes steel should be chosen in which the vanadium content is reduced to a minimum, or in which vanadium is replaced by other elements.

Acknowledgments

The author thanks J. Tichy and the staff of the metallographic laboratory at NHKG for their collaboration. He likewise thanks the management of NHKG for making it possible to carry out and publish this work.

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The cermets

ALTHOUGH IMPROVEMENTS in the high-temperature properties of many metals and alloys have in recent years been considerable, yet these in many instances have not sufficed to meet the high-temperature stresses imposed by such applications as the ram jet engine, the propulsion units in guided missiles and rockets, and in the latest type of atomic reactors.

High-melting point metals such as tungsten, tantalum, molybdenum and niobium whilst finding use as structural units in the temperature range 500–900°C. are not satisfactory at temperatures of 1,200°C. and upwards, chiefly because of lack of strength and low resistance to oxidation.

In comparison with metals, however, many refractory materials are stable at high temperature and exhibit superior resistance to corrosion but possess the disadvantages of low thermal conductivity and poor thermal shock resistance, *i.e.* they crack under sudden changes in temperature. In addition they are in general brittle and of low strength. In order to overcome these disadvantages efforts in recent years have been directed towards developing refractory materials of greater thermal stability by combining ceramics with metals. This work has resulted in the evolution of a class of material known as the cermets.

Work on the cermets was first initiated in Germany during World War II, with the intention of developing a material for use as gas turbine blading. The two raw materials most readily to hand at that period were iron and alumina, and although much work was expended on the system little success was achieved in obtaining the combination of properties required for the high-temperature application in view. After the war, the iron-alumina system was followed up in America by the substitution of chromium for iron and although this system failed to make the grade in jet engines, owing chiefly to poor thermal shock resistance, employment has been found for it in many other directions, such as high-temperature bearings, thermo-couple protective tubes, pressure vessels, etc.

TABLE I. *Typical examples of cermets*

Ceramic	Metal addition
Oxides:	
Al_2O_3	Al, Co, Cr, Fe
Cr_2O_3	Cr
MgO	Al, Be, Co, Mg, Ni
ZrO_2	Zr, Ni
ThO_2	Mo
Carbides:	
SiC	Ag, Si, Co, Cr
TiC	Mo, W, Fe, Ni, Co
Borides:	
Cr_3B_2	Ni
TiB_2	Fe, Ni, Co

Many metal-oxide phases that are being studied are shown in Table I.

Carbide cermets

The well-known tungsten cemented carbides are the earliest known examples of cermets, for these were the outcome of research conducted shortly after World War I and were linked up with the development of tungsten filaments for electric lamps. Filaments were originally made by mixing tungsten powder with gum or syrup, squirting through fine dies and then fixing the thread by volatilizing the binder in a protective atmosphere of hydrogen to prevent oxidation. Lack of ductility was, however, a serious shortcoming of the filaments.

The difficulty was finally overcome by the General Electric Co. Ltd., who briquetted the powder into small compacts and sintered in an inert gas, the treatment resulting in ingots of the metal. By alternating swaging (hammering) and heating, the ductility was gradually improved until finally a stage was reached when the metal was ductile at ordinary temperatures and could be drawn into wire.

The solution of this problem resulted in another, for the wear and tear on the expensive diamond dies used to draw the tungsten was very severe and proved extremely costly. Research resulted in a substitute, tungsten carbide, and not only did this prove efficient, but a further use was found for it, for when subsequently embedded and cemented with cobalt it was found tough enough to be used as a cutting tool, its quality not being impaired at a red heat.

Material which seems to be one of the most promising at present is based on titanium carbide. Several of these TiC cermets have been evolved and examination shows that these will conduct heat at a rate twice that of most refractory metal and alloys, and hence are of excellent shock resistance since this quality is proportionate to thermal conductivity. In addition they possess excellent stress/rupture characteristics. This property relates to the time dependency relationship of strength at elevated temperatures. As an example, the 100-hour life/stress/rupture resistance of some of the TiC base cermets is in the order of 12,000 lb./sq. in. as compared to 6,000 lb./sq. in. for some of the Ni and Co high-temperature alloys.

It would seem that the desired properties are dependent upon the purity of the basic materials and hence work has been concentrated upon this aspect. Thus the elimination of free carbon has

resulted in improved oxidation resistance and thermal shock resistance. This latter property is also influenced by the presence of certain bonding materials. Replacement of the early cobalt- or nickel-bonding metal by molybdenum and chromium have effected considerable improvement in this respect.

TABLE II. *Physical properties of cermets*

	1	2	3	4	Super alloy (for comparison)
Composition %:					
TiC	63·0	50·0	—	—	—
Cr	7·4	10·0	30·0	80	—
Ni	22·2	30·0	—	—	—
Co	7·4	10·0	—	—	—
Al_2O_3	—	—	70·0	20	—
Density (g/c.cm.) ..	6·0	6·4	4·6	6·0	8·3–8·7
Thermal conductivity (c.g.s. units) ..	—	0·06	0·023	0·022	0·035
Hardness (Rockwell A)	87	82	87	70	61–65
Oxidation resistance (wt. gain, mg./cm.^{2}) at 980°C.:					
After 50 hours ..	6·5	5·2	—	—	—
„ 200 „ ..	23·9	12·3	—	—	—
Tensile strength (1,000 lb./sq. in.):					
25°C.	26·2	30·5	35	—	110
650°C.	41·1	—	21	17·5	34–50
980°C.	37·8	—	18	—	9–25

Data collected from various sources.

Manufacture

Preparation follows the powder-metallurgy technique which can be briefly described as follows: (1) The powdered metal and ceramic, moulded to the desired shape, are compacted at pressures in the order of 10–30 ton/sq. in. (2) The compacts are then sintered at a temperature depending upon the constituents of the mixture. The two operations of compacting and sintering are also sometimes combined in one single operation, the method being known as hot pressing.

Success is usually dependent upon the formation of a bonding substance mutually adherent to both phases present in the mix. This bonding phase develops from the metal during sintering and enters into limited solubility with the ceramic. Bonding is often improved by permitting the metal to oxidize slightly, thus providing a metal oxide surface which is more compatible with the ceramic phase than a pure metal surface. An example of this type of bonding is found in the chromium/alumina cermet, in which the chromium during sintering is allowed to oxidize sufficiently to develop the oxide layer between the metal and ceramic phases, thus ensuring a strong adhesive bond.

It is known that metals bond better to metalloids than to oxides and thus another approach to bonding is to include metalloids such as borides or hydrides in order to interpose a transition phase between the ceramic and metallic particles.

A recent trend in the development and manufacture of cermets is the SAP (sintered aluminium powder) process. In this method, aluminium powder of approximately 1μ diameter is subjected to controlled oxidation until 15% of the aluminium is oxidized. Compacting at 20–30 ton/sq. in. and sintering at 550°C. is followed by hot pressing and extrusion. The characteristics of this product are that strength and hardness are well maintained at temperatures up to 600°C.

Investigations are proceeding to adopt the process to the production of high-temperature resistant metals and alloys, with or without the addition of small amounts of non-metallic powders such as silicides and carbides.

Recently, in the U.S., a new approach to the manufacture of cermets has been devised. Molten metals and ceramics are first flame-sprayed in alternate thin layers on to a rotating disc. The laminated mixture is then allowed to cool, finely crushed and hot pressed in a graphite mould at a temperature of approximately 2,000°C. Encouraging results are reported to have been attained by mixing 70–80% Al_2O_3 with 30–20% of stainless steel. This cermet possesses outstanding heat characteristics and is especially useful where extreme pressures are encountered, such as in nose cones of missiles and rockets.

Applications

It is apparent that while the cermets have so far failed, chiefly on grounds of poor thermal shock resistance, to make the grade in the usage for which they were originally intended, yet they possess several excellent properties which have been found useful in other directions.

1. *As corrosion-resistant materials.* For lining chemical reaction vessels and as thermo-couple tubes, where protection against molten metal is required. In pumps for handling liquid oxygen, fuming nitric acid and for combating the corrosive and erosive effects of high velocity gas impingement.

2. *Thermal shock material.* Brake linings, sparkplug points, high-temperature bearings and electrode contacts, rocket combustion chambers and missile components.

3. *Atomic reactors.* At present the fuel rating of uranium is restricted by the limiting strength of both the uranium and the magnesium alloy used as a protective sheath. Uranium becomes plastic at temperatures much above 450°C. and the magnesium alloy sheath begins to melt at 600°C.

With the development of atomic reactors requiring higher temperatures of operation for improved efficiency, materials such as the oxides or uranium, thorium and plutonium have received increasing attention. The advantages of these ceramics are that they possess high melting points and are in general corrosion resistant to the coolant. Like all ceramic materials, however, they are brittle, possess low thermal conductivity and low strength, and no ductility. These disadvantages may, however, be to some extent overcome by dispersion of the fissile ceramic in a metallic matrix, in other words the formation of a cermet. The ceramic can be UO_2, PuO, and the metal beryllium, zirconium or niobium. The cermet system can also be applied to include a completely fissile type such as uranium/UC or TH/UC.

The control of a normal reactor is exercised by the insertion of materials of high-capture neutron cross-section which absorb neutrons, thus permitting the power level of the reactor to be maintained at the desired level. Those in most common use are based on cadmium and steel containing up to 2% of boron. In reactors using highly enriched fuel and operating at high temperatures, alternative metals are being considered, and of these the rare earth metals have several desirable characteristics such as high-capture neutron cross-section and corrosion resistance.

These compounds, however, have a low impact resistance, and thermal shock resistance is not high. Since control and shut-down systems may be subjected to severe thermal and impact stresses it would appear likely that they will be developed as cermets.

Finally, it is to be noted that as the whole subject of cermets is still largely in the experimental stage, their true potential has yet to be ascertained, for they provide a unique combination of properties that undoubtedly will be more widely applied in the future.

Shrink fitting with liquid nitrogen

A 4-ton guide stalk on a 12,000-ton trimming and bending press has been shrunk by the use of liquid nitrogen before being fitted into its housing. The operation resulted in a perfect fit without distortion.

This method, using 45,000 cu. ft. of liquid nitrogen, was adopted in preference to expansion by heating of the cast steel housing into which the guide stalk was to fit. To have used this older method would have meant heating the casting for up to eight hours, during which time distortion would almost certainly have taken place. By using liquid nitrogen, manufactured and supplied by British Oxygen Gases Ltd., a saving of four hours was obtained, and there was no distortion to either component.

High-strength copper-titanium alloys

COPPER IS ONE of the world's oldest metals, titanium one of its newest. With 4·3% Ti added, copper has a tensile strength above 200,000 lb./sq. in. after cold working and precipitation hardening. Marketed under the trade name 'Amtite,' this alloy is now being used for electrical conductor plates and springs, and as a clamp die material in welding machines. Development is progressing rapidly, and many more applications are expected in the near future.

Recent work has produced strengths as high as 220,000 lb./sq. in.[1] These have been developed by capitalizing on the alloy's capacity to work harden extensively if prepared correctly.

Workability

Copper-titanium alloys can be readily hot and cold worked *when prepared in a high-purity form.* During melting and casting the alloy must be protected from contact with air. Even more important, a high-purity oxygen-free copper must be used as a starting material.

Alloys prepared from oxygen-free high-purity copper could be hot rolled down to the desired 0·285-in. gauge without difficulty. However, alloys prepared from the other types of copper exhibited surface cracking during the first pass, and frequently split down the centre on the second pass. A microscopic study showed relatively few inclusions in the oxygen-free copper alloys, but many inclusions were observed in the other alloys. These inclusions evidently are formed as a result of the reaction between titanium and various impurities in the copper base.

Copper-titanium alloys can be cold worked extensively without cracking if they are first solution annealed. After such a treatment, 0·250-in. and smaller gauge material can be cold worked over 90% without failure. This ability to absorb large amounts of cold deformation is important because work hardening contributes more to strength than precipitation hardening.

Investigation proves that titanium is a very potent strengthener of copper. The relatively high ageing temperature (400–450°C.) also indicates that these alloys have good high-temperature strength and stability. Fatigue and impact strength are also promising.

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Temperature uniformity in heat treating

HAROLD N. IPSEN

Rapid, uniform heating of charges of ferrous parts to temperatures within the critical range for carburizing, carbonitriding, or bright hardening can be effectively carried out by convection. Tests carried out to prove this are described by the author, president of Ipsen Industries Inc., U.S.A.

TEMPERATURE UNIFORMITY is important in the hardening process. In practically all steels hardenable by heat treatment, the character of the microstructure is determined primarily by the temperature at which it is formed. The minimum temperature at which austenitic solubility is complete is well established by available iron-carbon constitution diagrams for various steel compositions. Critical parts requiring dimensional stability or fine grain structures illustrate the care necessary for heating. Temperature variation as slight as ±14°C. may be sufficient to prevent full hardening of a part. Uniform heating is also essential where the work load has thick and thin parts that are intermixed, or parts where heavy machining stress is involved.

Improper processing produces parts that will fail prematurely. In many instances, inability of equipment to maintain a proper austenitizing temperature range will unintentionally result in only partial hardening. It is necessary to consider that even slight variations in composition and heat treatment may result in appreciable differences in structures and properties. All physical properties are lowered proportionately with hardness, but the greatest effect is noted on impact resistance and resistance to repeated stress above the endurance limit.

The degree of incomplete hardening that can be tolerated depends on the type of part. It is generally considered desirable that bolts and other parts subjected to substantially uniform tensile stresses be at least 90% martensitic. Aircraft fasteners would require complete hardening for acceptance.

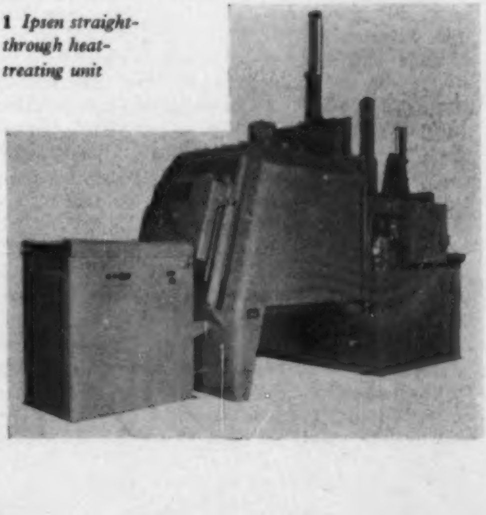
For applications involving high carbon and alloy steels normally subjected to severe service conditions, full-hardened structure becomes increasingly important. In a spring application, ability to resist a permanent set is dependent on full hardening. Maximum hardening of certain tool and die steels depends on complete solution of carbides, and requires uniform heating to temperatures up to 1,065°C. under close temperature control. This is especially true of steels containing appreciable amounts of Cr-Mo-V which precipitate large carbide compounds. While preheating is often considered essential, it is not required if the part is brought to soak temperature uniformly.

Effect on case and core properties

Temperature uniformity is especially important in case hardening because it controls the depth of penetration and carbon concentration. For example: in a normal 5-hour cycle, a maximum variation of 900-925°C. within a furnace will cause a range of 0·050 to 0·060 in. in case depth. At the lower temperature, it would require an additional carburizing time of two hours for a 0·060 in. case. This temperature variation could result in an equivalent, at 900°C., of ten hours' additional time for a case depth of 0·120 in.

Critical core properties and requirements for minimum amount of retained austenite call for restricted temperature ranges. The case-core relationship also influences the service effectiveness

1 *Ipsen straight-through heat-treating unit*



of a part. Close control of both structures must be maintained, especially on highly stressed parts such as ring gears, drive pinions, and transmission gears. In most applications, the prime importance of the core is to support the case, assuming that the core structure is of sufficient strength to resist bending or torque loads. For applications such as sheet metal screws, this latter requirement is critical. It presents a temperature control problem because a short heat cycle for case depth limitations, and a controlled soak at the carbo-nitriding temperature for complete core hardness are required. In most gear applications grain coarsening due to overheating must be controlled; otherwise surface compressive stresses may be substantially reduced.

Ammonia introduced into the atmosphere in the carbo-nitriding process increases the rate of penetration and solubility of carbon in the austenite matrix, and further reduces allowable temperature variations. Computing machine and typewriter components have extremely thin sections which must be held to a maximum case of 0·001 to 0·002 in. If the temperature varies more than $\pm 8^{\circ}$C., it is impossible to meet this requirement, even at temperatures as low as 760°C.

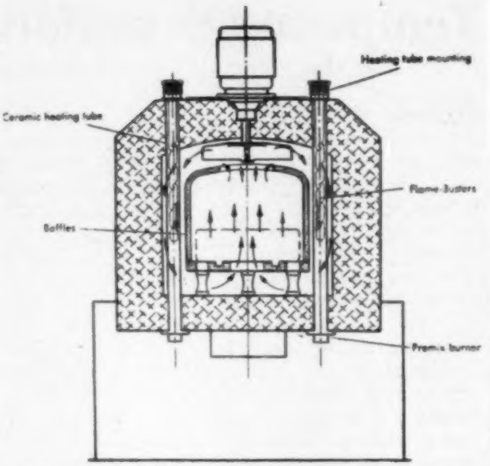
Effect of heat variables

To a limited degree, the effect of heat variables within a load reverses the tool heat treater's trick of restoring concentricity or straightness to a section by localized heating. Uneven heating induces stresses. Parts with irregular cross-sections and extensions are most susceptible to stress concentrations.

A secondary effect of heat variables, both in through-hardening and case hardening, is the loss of dimensional stability. Growth or shrinkage can be controlled with temperature variation by indirectly influencing microstructures obtainable. This phenomenon is directly proportional to the amount and rate of martensite transformation which can be influenced by the austenitizing temperature. The combination of high hardness and critical tolerances requires close process control. Deeply cased parts can be straightened only slightly before case fracturing occurs.

Furnace design

In the design of furnaces, certain 'rules of thumb' have been adopted in respect to heating capacity versus hearth area, time versus thermal head, and the concept of controlled heating rate to provide temperature uniformity in both thin and thick sections. However, the need for heating equipment to handle greater production in less working space and with greater efficiency has led to closer examination of these rules. Indications are that the use of



2 *Cross-section of furnace showing arrangement of fan, heating tubes, baffle, hearth and workload. Arrows indicate flow of controlled atmosphere*

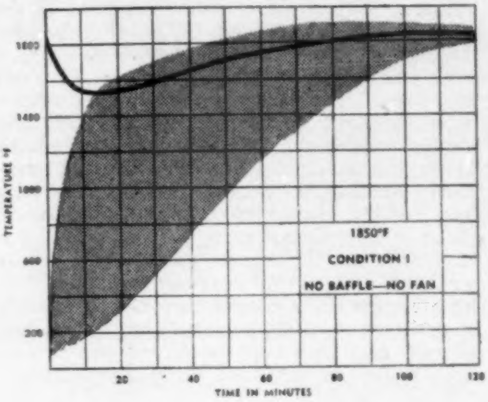
certain mechanical principles can measurably improve furnace performance.

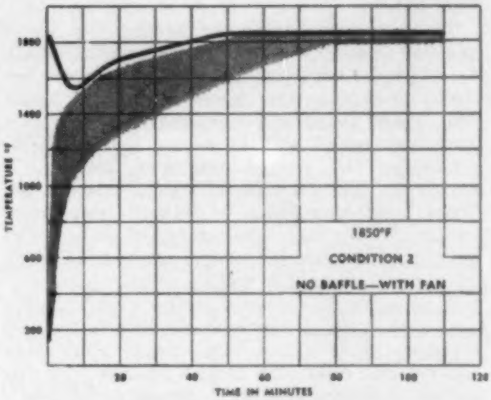
Furnace design relates hearth size to productive capacity, expressed as pounds of metal heated per hour to a given temperature, per unit of hearth area. Several authorities consider 30 to 35 lb./sq. ft. a conservative figure for ferrous materials heated to the lower hardening ranges. This was attributed to the concept that there was little or no transfer of heat by conduction and convection, and the major transfer of heat was due to radiation alone.

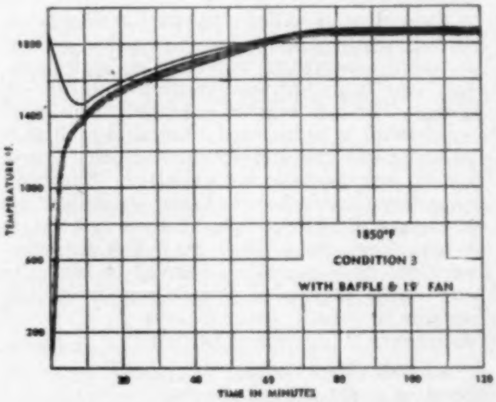
Tests to measure temperature variations

Convection heating at temperatures above incandescence is more effective than generally realized for controlling case depth, uniformity and distortion. Experimental work was performed to prove the point. The results led to the application of the principle of 100% forced convection heating in all Ipsen equipment.

Equipment used was the controlled atmosphere furnace shown in figs. 1 and 2. The hearth area is 24 in. wide, 36 in. long, with an effective working height of 18 in. The hearth floor is perforated with uniformly spaced openings equal to ¼ of its total area. Demountable sidewall and arch baffles are solid with a 14-in. square centre opening in the arch section. Above the roof opening is a 19-in. diameter centrifugal fan driven by a 3 h.p. 1,750 rev./min. electric motor. Eight vertical ceramic heating tubes, with flame busters, provide a maximum hourly input of 464,000 B.Th.U. Heated atmosphere is forced through each of the hearth







3 *Graphs showing temperatures recorded by the thermocouples under test conditions. Three sets of conditions are recorded for the 1,850°F. (1,010°C.) experiments: (1) No baffle, no fan; (2) No baffle with fan and (3) with baffle and fan. The upper edge of the shaded area is the reading from the centre of the workload. The lower edge of the shaded area is the reading from the edge of the workload. The black line represents readings of the control thermocouple placed beneath the hearth proper*

openings at a velocity of about 2,400 ft./min.

Two work baskets stacked to a total depth of 12 in. containing B 1112 steel stampings for bathroom scales were used in the tests. The gross load was 557 lb. A thermocouple, welded to a stamping, was placed in the exact centre of the work load. Another stamping with welded thermocouple was placed near the side and 6 in. from the bottom of the work load. Eight other couples were welded to separate parts and placed in random sections of the work load. The control thermocouple is located beneath the hearth proper, and is shrouded from direct radiation as much as possible.

All tests were conducted with controlled atmosphere to simulate production conditions. An endothermic generator was used, cracking air and natural gas at 2·5 : 1 ratio, and automatically controlling to a +30°F. dew point. The thermocouple lead wires were passed out through an atmosphere vent, which allowed all tests to be made under normal furnace pressures.

The load was tested at 840, 950, and 1,010°C. under three sets of conditions for each temperature:

(1) Without use of fan or baffles.
(2) With a 10-in. muddling fan over the charge, but without baffles.
(3) With a 19-in. dia. fan and directional flow baffle system within the heating chamber.

In each test the furnace was held at the test temperature for sufficient time to ensure equilibrium. A cold charge was then moved into the furnace, and the recovery time accurately checked with a multipoint potentiometer. Simultaneous checks were made of temperatures at all thermocouple locations in the charge, and of fuel gas consumption. At the conclusion of each test, the tray of parts was transferred to the quenching zone for atmosphere cooling. Graphs (fig. 3) show results of the centre thermocouple reading compared with the edge thermocouple reading, this comparison being representative of the other thermocouple recordings.

Test results

The poorest condition for heating was direct radiation (condition 1 for all temperatures tested). As might be expected, uniform temperature recovery throughout the charge is normally longer than under convection conditions, and becomes more pronounced with increasing operating temperature. The greatest detriment, however, is evident in the temperature spread through the charge upon completion of furnace temperature recovery. Also, there was substantial overshoot of the control temperature in parts adjacent to heating tubes where protective baffling was not present.

In using the 10-in. muddling fan without baffles (condition 2 for all temperatures tested), the fan, operating at 1,750 rev./min., forces atmosphere outward and downward to pick up heat from the surface of the heating tubes. Separate observation indicated that a minimum of heated atmosphere came into forceful contact with the bottom of the charge because short circuiting took place at levels substantially above the bottom of the furnace. However, recovery intervals were somewhat better than without the fan, and the temperature spread from the centre thermocouple to the outside thermocouple decreased.

A comparison test was made substituting a 19-in. fan without baffles (condition 2). The larger fan produced a slightly narrower temperature spread but considerable over shooting of the control temperature was noted.

The final tests studied the effects of guided, high velocity circulation (condition 3). In these tests no overshoot did or could take place because the temperature control thermocouple was in the atmosphere path from the heating tubes en route to the charge.

The importance of these observations is shown in further test comparisons. The hardness obtained by water quenching sections of S.A.E. 1045 steel from 730, 750 and 775°C. resulted in hardness values of 27 Rc, 51 Rc, and 58 Rc respectively. On the basis of test results, a theoretical 500 lb. load of S.A.E. 1045 parts austenitized from 840°C. without fan or baffles (condition 1), would recover as indicated by the control thermocouple in 50 min. Allowing 20 min. for soak (which would be normal practice), a considerable portion of the load would be under 730°C. and would not harden. Thus, a 260°C. temperature variation in the basket load would be present at time of quench. Under optimum circulation (condition 3), the same work load would be uniformly soaked out, resulting in full hardening.

A typical 0·008 to 0·010 in. case specification would be impossible under conditions 1 and 2 of the test. A 100-lb. load of small stampings was carbonitrided for one hour at 840°C. in the test furnace. With no fan or muffle (condition 1), the case ranged from 0·001 to 0·013 in. with 10-in. fan but no muffle (condition 2), 0·004 to 0·010 in.; and with standard fan and baffle (condition 3), 0·009 to 0·010 in. The additional case noted in condition 1 is attributed to temperature overshoot from radiant heat transfer. The light load allowed faster recovery at the centre than noted under test conditions. Results show evidence that the temperature had possibly reached 690°C. at time of quench. Since case penetration starts at about 675°C., it is imperative that the uniform heat-up of all parts of any given load be held as closely as possible from this temperature to control temperature. Soaking temperature is equally important, but a heavy load of parts may often have the desired case in some areas by the time they reach control temperature.

Conclusions

The benefit of baffled convection heating lies in the higher heating rate and uniformity from ambient to control temperature, with emphasis on temperature equilibrium between heating chamber and charge. In this uniform rise, the tendency of equalization is pronounced; thin sections heat at no higher rate than adjacent thick sections, regardless of their positions in the charge. The baffle gives directional flow of the heated atmosphere and minimizes direct radiation to parts adjacent to heating tubes. In addition, the baffles and brickwork provide a convenient reservoir of heat. An appreciable amount of stored heat from their surfaces is initially transferred to the stream of atmosphere for convection heating.

Forming moulds for drop forging

The Hydraulic Engineering Co. Ltd., Chester, have recently completed a 5,000-ton hobbing press for the largest drop-forging organization in the U.K. The latter organization has been operating a 2,000-ton hydraulic hobbing press for the past three years, and is now extending its range of operations.

The hobbing process, which has long been in use in the plastics industry, has only comparatively recently been adopted by the drop-forging industry, but is now arousing increasing interest as a means of forming relatively simple moulds much more quickly and cheaply than the normal die-sinking process. Dies for producing such things as spanners, small hand tools, rocking levers and small crankshafts are being made by hobbing.

In the hobbing process a female die, or mould, is formed from a master male die of special heat-treated steel. The male die is forced very slowly into a blank of normalized steel until the required depth is reached. The mould is then finished by machining, heat treatment and a final grinding or polishing operation. The speed of penetration must be as slow as possible to avoid splitting the blank. Speeds as low as 0·01 in./min. can be obtained by pump selection and a flow control valve

To increase its versatility and utilization the press is so designed that it can also be used for hot forging, or cold-flow forging, at a reduced tonnage and a higher ram speed.

Physical metallurgy

Developments in research techniques

At a meeting of Svenska Metallografförbundet at Stockholm last year, Dr. G. A. Geach, M.Sc., Ph.D., F.I.M., of A.E.I. Research Laboratory, described some recent developments in research techniques in the U.K. Although his lecture primarily brought British work to the attention of Swedish metallurgists, Dr. Geach has provided a useful survey of some techniques which are by no means too well known in this country, and it is felt that the following summary will be of interest. An illustrated report of the lecture was given in 'Jernkontorets Annaler,' 1959, (12)

WE TAKE FIRST a group of techniques in each of which some conventional property or operation is studied, but under unusual conditions chosen in order to reduce interfering phenomena or to emphasize properties not otherwise observed.

Low temperature work

A good example is work at the temperature of liquid helium. Thermal activation in a crystal lattice becomes so much less than at room temperature that effects can be observed which are masked at the higher temperatures. The mechanical properties of metals at liquid-helium temperatures, which Rosenberg has recently reviewed,[1] illustrate this point.

Experimenting at these temperatures was at one time work for specialists using elaborate facilities in special laboratories. This is no longer the case. The work of these pioneers has led to very simple apparatus for many types of experiment and it is now common for liquid helium to be carried on journeys lasting a few hours from centralized suppliers to laboratories using it. Following these developments we now expect considerably more use by metallurgists of experiments at these low temperatures.

Typical of today's simpler methods is the small cryostat developed by Rosenberg[2] for metallographic observation of specimens. This is a copper cylinder about 20 cm. long by 8 cm. diameter which, after evacuation, is disconnected from other apparatus and may be carried about freely, for example to a standard metallographic microscope. Within this cylinder are a small tank of liquid helium which is screened by liquid air, and the specimen which is thermally linked to the helium by a copper rod. The specimen lies just below a thin glass window.

Rosenberg used this cryostat to observe the low-temperature phase-transformation in sodium which Barrett had discovered by low-temperature X-ray work.[3] A small knife fitted in the apparatus prepares a surface for observation on the mounted specimen while it is in the evacuated apparatus. Rosenberg reported the extent of the transformation to be 45% at 20°K in unworked specimens, a proportion much greater than at one time supposed.

Another application of low-temperature work which may become important is the estimation from heat conductivity at low temperatures of the concentration of dislocations. At normal temperatures heat is conducted in metals mainly by electrons, the lattice vibrations being scattered by point defects in the lattice and playing a negligible part. At low temperatures the wave-lengths of these vibrations become so much larger that this scattering is reduced and heat transfer by the vibrations becomes a significant part of the whole. By studying alloys in which the solute reduces electronic heat transfer the part taken by lattice vibrations at low temperatures becomes so large a part of the whole that it can be measured.

There is a function of the thermal conductivity of an alloy which, if no change occurs in the structure of the alloy, is, at low temperatures, linearly related to the absolute temperature. The slope of the plot of this function depends upon the concentration in the alloy of strain fields large enough to disturb the elastic lattice thermal vibrations. Rosenberg believes that these strains are associated with dislocations, and not with other defects in the structure of the crystal. He gives the relation where $K/T=\alpha+(\gamma/Nb^2)T$ where K is the heat conductivity, T the absolute temperature, N the concentration of dislocations of Burgers vector b, and α and γ are constants.

Using this method of study he found the concentration of dislocations in brass to increase with

strain, slowly at first but rapidly between 10 and 30% extension, reaching a constant value which is higher for alloys of higher zinc contents. In fatigue the first few hundred cycles increased the concentration of dislocations rapidly to a value which then remained constant over several thousand cycles.

Creep under constant shear stress

Some years ago Andrade described a simple method for observing creep under constant shear stress,[4] and reported remarkable results. The specimen used was a disc having a circular groove cut in one face. The outer ring was clamped to a fixed frame and the inner circle rotated by an attached shaft.

Andrade found shear flow to continue proportional to the cube root of the time long after tensile creep had departed from this. He also found that on reversing the direction of shear metals of different crystal structure follow creep laws of different forms. It is a feature of this creep test that it allows repeated reversal of the strain. Andrade found shear flow to be entirely of the transient type which arises from glide within crystals, whereas tensile flow conditions give mixed transient and permanent flow, the latter attributed to the movement of grains as a whole and involving boundaries. Because of the form of the specimen a special furnace will have to be developed to use this interesting test at high temperatures.

Hardness testing at high temperature

Measurement of hardness at high temperatures has interested several workers as a simple and rapidly made measurement of a high-temperature property. Some of the earlier apparatus did not prove reliable, but this trouble no longer exists. A very well-proved testing machine which is useful up to 1,300°C. has been developed at A.E.I. Research Laboratory. The indenter, usually of Vickers form, can be made either of diamond mounted in molybdenum or, more usually, formed on one end of a fused alumina rod. It is loaded into the specimen by pressure of air in a metal bellows. Using a constant time of application of load, hardness as a function of temperature has been measured for a series of metals. If the logarithm of the hardness is plotted against the absolute temperature two straight lines of negative slope are obtained and these intersect at a temperature of approximately half the melting point. At temperatures below this, variation of the time of application of the load does not affect the hardness value but at more than half the melting point the apparent hardness decreases with increasing time of loading; this means that the indenter creeps into the material. It has been shown that the activation energy describing this rate of penetration of the indenter is similar to that for creep. Consequently high-temperature hardness testing can be used as a quick means of studying the creep properties of materials. For example, series of uranium alloys and zirconium alloys have been studied by this method and arranged in the same order of improving creep properties as was obtained by conventional tensile creep tests.

This test has proved to be very versatile and many other applications have been found for it. The apparatus has proved valuable as a means of deforming materials at high temperatures; it was so used in a study of the deformation in silicon and germanium. Etch structures in material below hardness impressions were observed. The effects of deformation at various temperatures were compared with the results of deforming at one temperature and then annealing at a higher temperature. In this way it has been demonstrated that changes which occur on annealing a deformed specimen for several hours will take place in a few seconds in a specimen annealed while under a stress applied as the hardness load.

It is usual when studying age-hardening to interrupt the process by cooling the specimens for examination. However, the process may conveniently be measured while it is occurring at high temperature by making a series of hardness impressions as time proceeds.

The annealing of cold work has also been studied by heating a specimen rapidly and then observing any change in hardness with time at constant temperatures. Specimens examined at a few temperatures quickly provide a full picture of the change in properties with time and temperature.

Direct observation of dislocations

Outstanding among new methods of observation is the application of the high-resolution electron microscope for the direct observation of dislocations. Two years ago 'direct evidence of the properties of dislocations . . . was . . . very narrowly circumscribed.' 'Decoration' in a few transparent crystals and deductions from etched surfaces were the best available. About that time Hirsch developed his method[5] of seeing dislocations by transmission electron microscopy of foils so thin as to be transparent to electrons. Modern high-resolution microscopes made this work possible because in them very small areas on the specimen are 'illuminated' at high intensity without overheating, rather than because extremely high resolving power is used directly.

Nearly all the observations reported from the early applications of this technique had been predicted on theoretical grounds. An example of this is the pile-up of dislocations when their move-

ment through a crystal is impeded. Interaction between dislocations which lie on closely-spaced parallel planes and cross each other is another phenomenon which has been seen clearly. New dislocation phenomena are now being discovered by this technique. Cottrell has suggested that we now know all about dislocations that can be deduced from simple elasticity theory and that extension of our knowledge must now come from direct observations rather than theoretical work.

The occurrence of simple geometric loops which are formed by the condensation of the excess vacancies in quenched metal had been suggested as a possibility,[6] but these loops could not be seen before the introduction of the technique of looking into thin films by electron microscopy.[7] Because a grain boundary acts as a sink for vacant sites and removes these from its neighbourhood loops are not formed near a boundary. It was found that in gold these loops split up into figures bounded by stacking faults.[8] This had not been foreseen and can occur because the stacking-fault energy is low. In aluminium the stacking-fault energy is high and the loops are formed of whole dislocations.

Dislocations of helical form have been seen[9] in quenched metals. In these each dislocation follows a corkscrew-like path through the crystal. The formation of these can be explained by condensation of vacancies on to screw dislocations.

X-ray microanalysis

Another method of observation now receiving attention in Britain and in several other countries is X-ray microanalysis. In principle this is a very simple technique. An electron gun and suitable lens system focus a fine beam of electrons on to a selected half-micron spot on the specimen. The X-rays emitted are analysed for intensity and wave-length. After calibration of the apparatus by work with samples of known composition the unknown composition of the point on the specimen may be determined quantitatively. It is clear that this procedure will be used in studies of many metallurgical problems. It will be particularly valuable in examination of fine particles in alloys and in composition changes, particularly those which occur across irregular surfaces. Three British laboratories have built machines for this and one is about to come on to the market. One of these machines detects elements of atomic number 12 (magnesium) and above: it is planned to take its recording down to carbon ($Z=6$), making important additions to the range of problems which may be tackled.

The apparatus can be employed in several ways. The most usual is to record the intensities of X-rays of different elements at a point on the sample by counting apparatus. A new method of considerable value in special applications shows on a cathode ray tube a magnified picture of the specimen as 'seen' by the radiation from one element. This is done by putting deflector plates near the electron beam in the microanalyser and using these to make the electron spot scan a small area of the specimen. Similar plates in the cathode ray tube move the recording spot in phase with the analysing electron spot. Since the brightness of the cathode ray spot is related to the intensity of X-rays of one chosen wave-length coming from the specimen one obtains a picture of the distribution of one chosen element in the area 100 microns square which is observed.

Arc furnaces

As a last group of techniques I take certain applications of arc and electron bombardment heating. During the last 20 years employment of furnaces of the type in which material placed upon a cool inert hearth is heated by an arc struck to it has become universal. It is interesting, as an aside, that R. Hare of Philadelphia described such a furnace in 1839.[10] New applications of such furnaces call for publicity because they can be so widely useful.

One which I consider particularly helpful is to anneal specimens in the arc furnace. Temperatures in the range 1,300–3,000°C. have been held quite precisely and for long periods. Annealing may continue for several hours and little attention is required. Several methods are used; specimens vary in form and size, but are always small.

Another valuable application of the arc furnace is for the measurement of melting points.[11] A small bead of alloy is so heated by a suitably adjusted arc that the top half is melted and the bottom solid. A disappearing filament optical pyrometer is used to measure the temperature of the interphase junction. When this is done for metals of known melting points it is, of course, found that the observed melting points are lower than the true melting points, but when these are plotted against one another all points lie on one smooth line. Using this line it is possible to obtain unknown melting points. This procedure is easy and quick to apply. Several beads of alloys can be enclosed in the furnace and their melting points measured in rapid succession: it is quite possible to make up all the alloys required for the study of a binary system and measure their melting points in one afternoon. Melting points of refractory oxides and many other non-metals can also be measured in this way, although there is greater uncertainty about the true temperatures. However, results are still of interest as they do show the form of the melting point curves and the true compositions at which changes in the curves occur.

Heating by electron bombardment

Heating by electron bombardment is not new but it has recently been used extensively and in novel applications. In principle the method is simple. A high-voltage difference drives electrons from a hot filament to the sample which is heated by their energy. To suit many applications of this method of heating the electrons may be focused on to a small area. It has also been shown to be possible to deflect the electron beam by suitable electron optics from the path of atoms leaving the filament, so that these do not reach and contaminate the specimen being treated. It is a valuable feature of many applications of this technique that it must be carried out in a good vacuum. It is also important that a melted specimen is not stirred vigorously. This has made it possible to purify uranium from oxide inclusions, for uranium oxide is lighter than the metal and floats to the top of an undisturbed melt.

This method of heating has been applied for zone melting. A floating zone in a vertically mounted rod of metal or other material is melted. Single crystals of many refractory metals and alloys have been produced by passing a molten zone once along the specimen; this is proving a very valuable service to research in physical metallurgy.

Heating by electron bombardment has recently been used in a high-temperature X-ray camera. Specimens in a demountable vacuum vessel have been heated above 3,300°C. in this camera; the power required is small (50–60 watts maximum) because only the specimen is taken up to high temperatures.

Acknowledgments

The author thanked various friends who had given him advance information on their work. He was indebted to his own colleagues, and in particular to Mr. F. O. Jones, who had helped him in preparing his lecture, and Dr. T. E. Allibone, F.R.S., Director of the Laboratory, for permission to publish.

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BOOKS

Materialprüfung mit Röntgenstrahlen unter besonderer Berücksichtigung der Röntgenmetallkunde

By R. Glocker. Fourth edition, Springer-Verlag, Berlin, 1958. Pp. 530. *DM.* 61.50.

ALTHOUGH LARGELY based on earlier editions, the present book has been considerably extended and brought up to date. It is divided into four chapters, dealing with the generation and properties of X-rays, the theory and practice of non-destructive testing by means of X-rays and gamma-active isotopes, X-ray fluorescent analysis of alloys and, finally, the use of X-rays in studies of internal stresses, phase changes and other aspects of the fine structure of materials, mainly metals.

The book is written in a lucid, straightforward manner; mathematical details have been kept to the essential minimum and relegated to an appendix. A large number of illustrations, including photographs of modern equipment used industrially as well as for research, add further to its value.

For purposes of reference and guidance to the practical and theoretical worker in this field it should prove to be an invaluable source.

P. FELTHAM

Metal fatigue

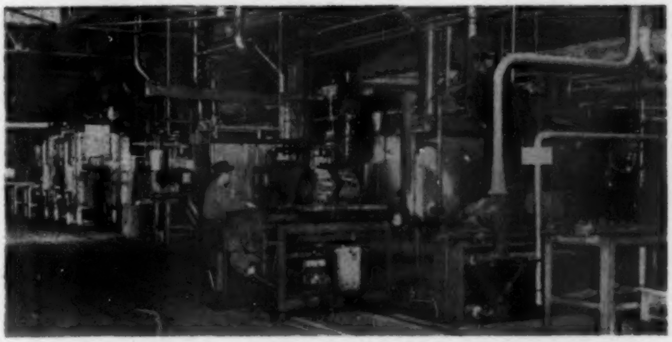
Edited by George Sines and J. L. Waisman. Published by McGraw-Hill Book Company, Inc., New York, 1959. Pp. 415. Illustrated. £4 17*s*. net.

IT WOULD probably be true to say that the insidious problem of metal fatigue has received more practical and fundamental attention than any other single engineering topic. The ever-increasing output of scientific papers bears witness to the continued interest in this problem and must present a frightening picture to any engineer freshly engaged in designing an economical machine or structure which will not fail under repeated stress. Such an engineer could undoubtedly benefit from the publication of this volume, for most of the major issues in metal fatigue failure have been singled out for rational treatment. In addition, each chapter contains a selected bibliography which can be considered as representing the developed concepts and techniques up to around 1955. In this connection, it is considered most unfortunate that practically no reference is made to the numerous papers presented three years ago at the 1956 International Conference on Fatigue of Metals, sponsored by the Institution of Mechanical Engineers in co-operation with the American Society of Mechanical Engineers, and held in both London and New York.

The book is divided into six parts and contains a total of 17 chapters. Both the theoretical and practical aspects of fatigue failure are considered and, although the latter aspect has a strong aeronautical bias, the principles involved are generally applicable to any other field where machines and structures are subjected to repeated stresses.

The book is liberally illustrated with clear line drawings and photographs and, despite the fact that it represents the individual efforts of 16 contributors, there is surprisingly little duplication in content. For the metallurgist, however, the book could only be expected to hold a marginal interest, while it is doubtful if the engineer, already conversant with fatigue, would find much fresh information between the covers.

H. K. LLOYD



One-man heat-treatment line

Operator using the shuttle bogie to charge parts into furnace

A RECENTLY INSTALLED straight-line arrangement of batch-type furnaces has solved a difficult production problem in the heat-treating operation at the Harnischfeger Corporation plant, Milwaukee, Wisconsin, U.S.A. Only one man operates all the equipment, which comprises a Super Allcase controlled-atmosphere hardening furnace, propeller-agitated hot oil quenching, two controlled-atmosphere recirculating tempering furnaces, two atmosphere generators, automatic timing and temperture control. A unique handling system, using a motorized shuttle-bogie type transfer table on roller rails in front of the furnaces, permits the operator easily to deal with individual parts or work loads weighing hundreds of pounds.

Harnischfeger manufacture large overhead travelling cranes and hoists, excavators and truck cranes for mining, construction work and road building, and a large part of their production consists of pinions, gears, rollers, shafts and pins ranging up to 6 in. dia. Alloy steels in the 4,100 and 4,300 series, as well as cast steels of similar compositions, are used. Normal hardening temperatures range from 800 — 870°C. Carburized parts produced from 8,600 and 4,300 series steels are similarly treated.

Hardening furnace

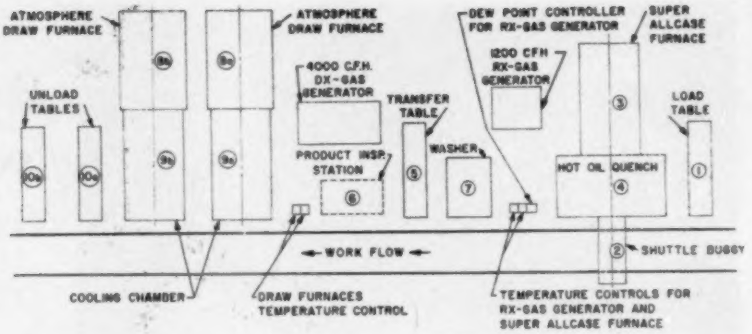
At the Harnischfeger plant the hardening furnace is of the enclosed quench type and completely automatic. The furnace-heating chamber, heated by suction-type radiant tubes, has a work space of 30 in. wide, 48 in. long and 18 in. high. A roof fan circulates the atmosphere gas around the tubes and through the work load. Although primarily used for clean hardening, the 980°C. max. temperature range makes it available for carburizing purposes as well. The necessary enriching panel with automatic valves and flow meters is an integral part of the furnace.

Hot oil is circulated within the enclosed quench tank, and through coolers to maintain temperature control throughout quenching. Propeller agitators provide forced oil circulation around and through the load, affording a better and more effective quench. A 1,200 cu. ft./h. Surface RX gas generator supplies the necessary atmosphere for this furnace, as well as for a large radiant-tube pit furnace installed nearby and used for similar purposes.

Further, to minimize operator attention, a Surface Autocarb, automatic signalling dewpoint controller, monitors the RX gas generator and provides a constant analysis atmosphere at the hardening furnace. This combination supplies and controls a furnace atmosphere which permits a furnace production of an average of 460 lb. of net work per hour substantially free of surface decarburization. The enclosed quench ensures freedom from surface oxides or scale.

Tempering operation

Tempering of the hardened parts is carried out in either of two identical tempering furnaces, having an operating range of 200–670°C. The heating chambers are similar in size and design to the hardening furnace to accommodate the same tray size and load. Suction-type radiant tubes are used for heating to permit the use of controlled atmosphere. Roof fans accelerate the heating rate by convection and provide uniform heating of the work. The vestibule used for charging and discharging the furnace is provided with an overhead cooling chamber. This feature permits loading the furnace with fresh work while the previously tempered load is being further cooled in the same atmosphere as used in the furnace. Most of the work is tempered in a 560–650°C. range. Use of a DX generator gas atmosphere not only eliminates scaling at these temperatures, but produces an acceptable surface finish without the need for



Schematic layout of the straight-line heat-treating plant

blasting operations. Handling is cut to a minimum, and possible sources of nicking heavy and expensive parts is reduced.

Handling facilities

One man operates all of the heat-treating facilities in this particular straight-line arrangement. This is accomplished primarily by means of a shuttle-bogie, which the operator actually rides. The bogie runs on two floor rails installed over the full length of the heat-treating line.

The trays are loaded at a work station by the operator, and automatically moved on the shuttle-bogie as required. The operator, riding the running board of the loaded bogie, conveys the load to the hardening furnace. The furnace door is opened, and a transfer chain on the bogie charges the trayload of parts into the furnace vestibule, and the door closes. From here the operation, which consists of transfer to heating chamber, temperature, time at temperature, removal for quench, and positioning for removal from the furnace itself, is automatic.

At this point the transfer chain removes the load from the furnace and places it on the shuttle-bogie to be transported to the spray washer. After removal of excess quenching oil, the trays are moved to a holding rack. Here the parts are permitted to cool further for completion of metallurgical transformation and to permit surface inspection and 'as quenched' hardness checks. Several types of hardness testing equipment are incorporated in the line at this point.

After such checks the trays are again 'chain transferred' to the shuttle-bogie, transported to one of the two tempering furnaces, conveyed into the vestibule and again automatically processed through the tempering cycle. After tempering, the trayload of parts is automatically transferred to an overhead cooling chamber in the furnace where it is cooled below excessive scaling temperature. The loaded trays are again transferred to the shuttle-bogie and moved to the unloading station. Complete inspection is now made on the heat-treated parts and they are then passed out to assembly or for final machining operations.

With this straight-line arrangement wasted motion, unnecessary handling, confusion and lost time have been minimized by the streamlining of the operation. Mechanical handling methods, automatic controls, and fully protected safety equipment permit complete operation with further economy because of the single operator required. A higher quality product is also obtained, the use of atmosphere-controlled equipment readily permitting heat treating finished or semi-finished parts to impart mechanical properties where they are most needed.

All the equipment installed at the Harnischfeger plant was built by Surface Combustion Corporation, Toledo, Ohio, for whom British Furnaces Ltd., Chesterfield, are the U.K. representatives.

Electron microscopy (Jan. issue)

A simple extraction replica for the study of fine-grain phases—JAROSLAV JEZEK.

Concluded from page 27

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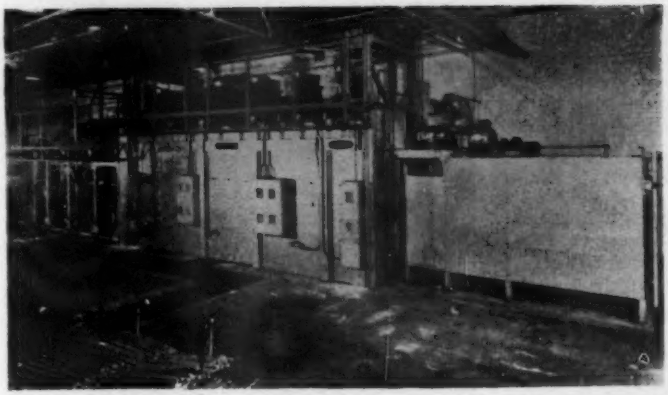


Heat treating gun barrel forgings

View of the tempering furnace line with the pusher mechanism on right

EQUIPMENT used in the manufacture of small arms must give high production, be economical in the use of labour and materials and simple in operation. The general streamlining of the armed forces in recent years and the standardization of a number of weapons amongst the NATO Powers have tended to reinforce these points. High production units have been set up in a number of ordnance factories employing the latest techniques and equipment. This has occurred on a large scale at the Royal Ordnance factory, Fazakerley.

An interesting unit which has recently been installed there is a fully automatic continuous hardening and tempering furnace for the treatment of carbine barrel forgings. The unit was designed and built by G.W.B. Furnaces Ltd.

Previously barrel forgings had been treated in gas-fired batch furnaces, served by a single traversing charging machine. Hardening, tempering and quenching had been separate operations, each one requiring the use of the charging machine. The forgings had previously been loaded horizontally, and this led to an appreciable percentage suffering some measure of distortion during the heat treatment. This has now been substantially reduced.

The new furnace requires only one operator to supervise control, loading and unloading. The different sections of the furnace are linked by conveyors and the separate operations are carried out automatically, thus high productivity is obtained and supervision is reduced to a minimum. Refinements in the actual heat treatment and the use of special suspension jigs for the forgings produce a better finish and effect a considerable reduction in the quantity of rejected material. The unit is adaptable in that, if required, the hardening and tempering sections of the furnace can be worked separately and the various sequences can be adapted to suit changing requirements.

The complete installation comprises one pusher-type hardening furnace with an automatic quench and a degreasing unit, together with a pusher-type tempering furnace, also equipped with quenching and degreasing plant. Both the quench units are equipped with oil-circulating pumps and oil coolers, and a G.W.B. protective atmosphere plant is employed for use with the hardening furnace. The hardening furnace with quench tank and degreaser are linked to the tempering furnace with its quenching and degreasing units by cross-traversing conveyors.

Hardening furnace

Barrels are suspended from specially constructed heat-resisting jigs, each capable of carrying eight forgings, loading and unloading being effected whilst the carriers are on the final cross-traversing track conveyor. The loading sequence is approximately 7½ min. Forgings to be treated are conveyed automatically under the pivoted head of the hardening furnace hydraulic pusher, which is of overhead mounted design. This pusher conveys the carriers separately into the hardening furnace. The effective dimensions of the hardening furnace are: heated length 13 ft. 4 in., width 9 in., height 3 ft. 3 in. A rating of 120 kW. is included in two independent automatically controlled zones, giving a maximum temperature of 900°C. Normal operating temperature is 850°C. with soaking times of 1–1½ h. The unit was designed for a nominal consumption of 73 kW/h. at 850°C. Robustly constructed with a gas-tight casing, the furnace is well insulated to minimize body losses. Two rows of heat-resisting skid rails support the charge carriers during

their passage through the furnace. Heavy-section 80/20 nickel-chromium strip heating elements are arranged on the side walls of the chamber, supported by a special hook suspension method. At each end of the furnace is an electrically-operated fully-insulated counterbalanced door. Fitted to the base of the entrance door is a unit section of skid rails used for alignment purposes during charging operations.

A gas-lock chamber is situated at the entrance of the hardening furnace, whilst at the exit is fitted a gas-tight quenching hood, the bottom edges of which are immersed below the level of the quenching medium. In addition to preserving the protective atmosphere, the quenching hood also ensures that the charge ready for immersion is completely free from the cooling effect of draughts and tends to produce constant uniform quenching temperature.

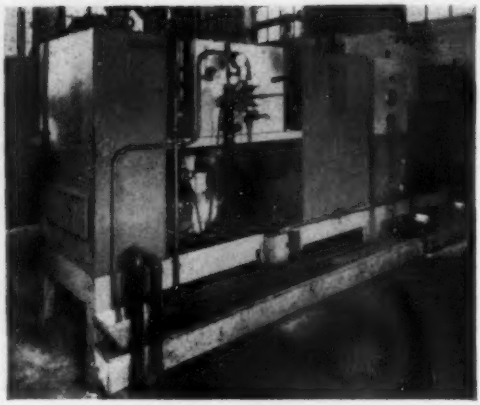
As the pusher propels the carriers through the furnace an extractor gear is timed to remove the carrier from the furnace chamber on to the platform of a quenching hoist. The extractor gear comprises a steel frame sited immediately above the quench tank and the extractor head is provided with a pivoted pawl.

Immediately the extractor gear has removed the charge carrier from the furnace and deposited it on the quench hoist platform the platform automatically lowers and places the carrier on to the quench conveyor, which conveys the charge through the quenching medium and also through the degreasing unit. The approximate dimensions of the quench tank are 10 ft. long × 3 ft. 3 in. wide × 4 ft. deep.

In the gas-heated degreasing unit the barrels are sprayed from a battery of fixed jets which are supplied with degreasing solution from a motorized pumping unit. In the base of the degreaser is situated a gas-heated coil which controls the temperature of the solution by means of a 4-in. dial thermometer.

Tempering furnace

A further extractor gear, similar in construction to that previously mentioned, removes the charge carrier from the quench conveyor and transfers it on to a traversing conveyor; by this arrangement the charge carriers are conveyed into the tempering furnace line. The traversing conveyor is fitted with T-section attachments to accommodate charge carriers. On reaching the tempering furnace line the charge carrier is pushed from the traversing conveyor into the tempering furnace by a second pusher gear. The effective dimensions of the tempering furnace are: heated length 20 ft., width 9 in., height 3 ft. 3 in. With a rating of 90 kW. in three independent automatically-controlled zones, the unit has a maximum temperature of 650°C. Generally, the tempering furnace is similar in construction to the hardening unit, but since no protective atmosphere is employed the fittings connected with this process are not present. Different types of forgings are soaked for periods ranging from 1½–3 h. at temperatures up to 650°C. Since these treatments are in the lower temperature ranges, some form of air circulation is necessary to provide efficient distribution of the heat. To this effect, four air-circulating fans are situated in the furnace roof and baffles of heat-resisting alloy are specially situated to give directional air flow over the heating elements and through the working space.



G.W.B. endothermic burnt town's gas plant with silica-gel drying unit

Quenching and degreasing arrangements, together with the extractor and conveyor systems, are similar to those in the hardening furnace line, so that a continuous conveyor system is formed linking all operations.

Associated equipment

Each of the furnaces is provided with its own set of electrical equipment, all of G.W.B. manufacture. The switchgear comprises two iron-clad contactor cubicles, one for each furnace, and a totally enclosed motor panel housing 60 motor contactors for the various pusher, extractor, hoist and conveyor drives. Automatic temperature control for both furnaces is provided by a common instrument control panel. A complete sequence of operations for the installation is carried out automatically and all the necessary limit switches and similar interlocks are controlled from a master sequence time switch in the instrument control panel. The protective atmosphere plant is a standard G.W.B. burnt town's gas exothermic unit having a capacity of 1,000 cu. ft./h. and linked with a G.W.B. silica-gel gas-drying plant.

ELECTRON - MICROSCOPE SYMPOSIUM

A SYMPOSIUM on the 'Application of thin-film techniques to the electron-microscopic examination of metals' was held last November in London by the Institute of Metals. The papers, which will be published in the journal of the Institute, are abstracted below.

Techniques for the direct examination of metals by transmission in the electron microscope. By P. M. KELLY, B.A., and J. NUTTING, M.A., B.Sc., Ph.D.

Although replica techniques have been used with great success for the examination of metals, these methods have their limitations. With the development of instruments having high resolving power and fitted with a double condenser lens that enables high beam intensities to be obtained on the specimen, a new approach has been made to the problem of preparing metals in a form suitable for examination by transmission in the electron microscope. During the past few years a number of suitable techniques for preparing metal foils with a thickness of 100–2,000 Å. have been devised. These techniques are reviewed in this paper and can be classified into three principal groups:

(a) *Deposition* methods involve the production of metal foils by condensation of the metal vapour *in vacuo*, the precipitation or electrodeposition of thin crystals from aqueous solution, and the casting of foils from the liquid state. These techniques are of limited use only, since the results obtained from foils prepared in this way are seldom typical of bulk material.

(b) *Deformation* methods used to prepare thin foils comprise beating and machining in diamond-bladed microtomes. The former is very limited in its application, but the latter shows interesting possibilities, particularly for the examination of multiphase alloys.

(c) *Dissolution* techniques are perhaps the most generally applicable to the preparation of foils of pure metals and alloys. The methods adopted have involved simple chemical etching, ionic bombardment, and electropolishing. The latter is the most successful and has been widely used, since it is thought that the structures obtained from foils prepared in this way are typical of those to be expected in bulk material.

An outline of the theory of diffraction contrast observed at dislocations and other defects in thin crystals examined by transmission electron microscopy. By M. J. WHELAN, M.A., Ph.D.

The formation of contrast on transmission electron micrographs of crystalline materials depends on diffraction. The contrast near defects that produce lattice displacements (*e.g.* stacking faults, dislocations) is essentially a phase-contrast effect, the phase variation arising through displacements of atoms from their normal positions. The dynamical and kinematical theories of diffraction are discussed. The kinematical theory can be developed in a particularly simple form with the aid of amplitude-phase diagrams; this concept is very useful in discussing qualitatively the types of contrast pattern expected near dislocations where the displacements vary continuously. Many features of the contrast at dislocations can be explained on the kinematical theory, including the nature and width of the contrast, double images of dislocations, and invisible dislocations.

Observations of dislocations in metals by transmission electron microscopy. By P. B. HIRSCH, M.A., Ph.D.

This paper reviews the results obtained so far from studies involving direct observation of dislocations in metals by transmission electron microscopy. The technique has been used to study both fundamental properties of dislocations and the distribution of defects as a function of treatment of the specimens. The former category includes observations on glide, partial dislocations, stacking faults, cross-slip, dislocation interactions and nodes, low-angle boundaries, interactions between point defects and dislocations, climb, and dislocation sources. The latter class includes results on distributions of dislocations and dislocation loops in specimens deformed in tension or in fatigue, after recovery or recrystallization, quenching, and radiation damage. Some suggestions are made as to the probable trends of future applications of this technique.

The observation of anti-phase boundaries during the transition from CuAu I to CuAu II. By D. W. PASHLEY, B.Sc., A.R.C.S., Ph.D., and A. E. B. PRESLAND, B.A., B.Sc.

Thin single-crystal films of copper-gold (CuAu) alloy have been examined by high-resolution electron microscopy, and the domain structure in both the CuAu I and the CuAu II superlattices has been revealed. The arrangement of the anti-phase domain boundaries is shown to be modified by the presence of dislocations.

The specimens have been annealed inside the electron microscope, so that the transition from CuAu I to CuAu II has been observed in detail. It is found that the transition does not involve any dislocation mechanism.

The significance of the results in relation to the mechanical properties of ordered alloys is discussed.

Electron-microscopic studies of precipitation in aluminium alloys. By R. B. Nicholson, B.A., G. Thomas, B.Sc., Ph.D., and J. Nutting, M.A., B.Sc., Ph.D.

As a result of the development of the thin-foil transmission method of examining metals directly in the electron microscope, a completely satisfactory technique is available for any alloy system which will allow the detailed morphology of the ageing reactions to be determined, while selected-area electron diffraction of the specimen in the electron microscope enables the structure of the precipitated phases to be obtained. Thus, these new techniques, used in conjunction with kinetic studies, enable an almost complete account to be given of the structural changes occurring during the ageing of alloys.

The improvement in the quality of the results obtainable during the past few years reflects improvements not only in the specimen-preparation techniques, but also in the design of electron microscopes. Many of the micrographs shown can be obtained only in an instrument of high resolving power fitted with a double condenser lens. For this investigation the Siemens Elmiskop I was used.

With the development of a generally applicable electropolishing thinning technique, a range of aluminium alloys has been examined.

Metallographic examination has revealed new features in the structure of the supersaturated solid solution; zone formation has been detected and the transition from zones to intermediate precipitates followed. Under some conditions the formation of intermediate precipitates on dislocations was observed. The interaction of moving dislocations and precipitates has been studied and enables a more complete explanation to be given of the phenomenon of age-hardening.

Electron-microscopic observations on the recrystallization of nickel. By W. Bollmann, Dipl.phys., Dr.Sc.nat.

The various stages in the recrystallization of pure nickel have been studied by transmission electron microscopy and hardness measurements. The observations on the nucleation of crystal grains can be interpreted according to the theories of Cahn and Cottrell. The appearance and origin of certain 'growth zones' visible inside crystal grains are discussed.

A great deal of research work has been done on the recovery and recrystallization of cold-worked metals; the subject has been reviewed by Beck. The main experimental techniques so far applied are: optical microscopy, X-ray diffraction, strain and indentation hardness measurements, microcalorimetry, and electrical-resistance measurements. The method described here is transmission electron microscopy, which provides more information than the replica technique owing to the possibility of direct observation of dislocations and to the combination of microscopy and selected-area diffraction.

Microscopy is useful for the study of individual localized effects, but suffers from the disadvantage that it is difficult to obtain a true overall view. However, in the present work, a large number of pictures have been taken at each annealing stage and those reproduced have been chosen as representative of the average state of the material.

The martensite transformation in thin films of iron alloys. By W. Pitsch.

When austenite transforms to martensite in massive material, the transformed region, at least at the beginning of the process, is entirely surrounded by austenite. At the interface between the two phases small strains and rotations only are permissible, for the interface energy must be low. This condition severely restricts the transformation mechanism by which the interface is determined, since the atoms cannot move into positions of low energy by diffusion processes. Moreover, the volume change that occurs during the transformation sets up stresses and causes lattice distortion. Therefore, the ideal transformation mechanism by which austenite originally transforms to martensite may not be valid for massive material.

To check this possibility, the martensite transformation has been studied in thin films, where constraints must necessarily be smaller than in massive material. The binary systems investigated were iron-nitrogen, iron-carbon, and iron-nickel.

The growth, structure, and mechanical properties of evaporated metal films. By G. A. Bassett, M.Sc., and D. W. Pashley, B.Sc., A.R.C.S., Ph.D.

An evaporation technique for preparing uniform continuous single-crystal films of gold of $\sim$150 Å. and upwards in thickness is described. The microstructure of these films has been examined by transmission electron microscopy, and they are found to contain a high density (10^{10}–10^{11}/cm.^{2}) of dislocations. The mechanism of formation of the films has been investigated experimentally, but no direct evidence of how the dislocations are introduced has been obtained so far.

Some of the films have been examined during controlled deformation inside the electron microscope; they have an abnormally high tensile strength, and deform elastically up to strains of $\sim$1%. Catastrophic fracture then occurs, the mechanism of which has been deduced from the detailed examination of the specimens after fracture.

The relationship between the microstructure and the mechanical properties of the films is discussed.

NEWS

Britain's largest electric arc furnaces

FOLLOWING THE RECENT STATEMENT of the United Steel Companies Ltd. that they are to spend £10,000,000 installing what will be the largest electric steelmaking plant in the world at their Steel, Peech and Tozer branch, G.W.B. Furnaces Ltd., of Dudley, Worcs., announce that they are to supply the first two giant electric arc furnaces for the project.

These furnaces will be almost twice as large as any previously built in Great Britain. The electrical demand of the two furnaces will be equivalent to that of the town of Huddersfield, each furnace having an electrical rating of 40,000 kVA.

The G.W.B. arc furnaces will be of Demag design although, apart from the regulator, the equivalent of which is unobtainable in this country, the units will be entirely of British manufacture, the steel construction being carried out by Distington Engineering Co. Ltd., a subsidiary of United Steel Companies Ltd.

Each furnace shell will have an internal diameter of 24 ft., a nominal capacity of 150 tons, and will be capable of melting at the rate of 1 ton/min. In practice the furnaces will be used for a maximum of 110 tons ingot weight. Construction of the furnaces will follow the well-known Demag kingpin or gantry design in which the roof is the only item lifted from the shell when the top charging takes place. The weight of the electrode equipment is permanently carried by the gantry which, after raising the roof, swings aside for furnace charging around a kingpost.

On completion of the scheme in five years' time, six electric arc furnaces will have replaced 21 open-hearth furnaces and 14 120-ft. high chimneys will have been demolished. The total output of the finished plant will be 1,350,000 ingot tons of steel per year.

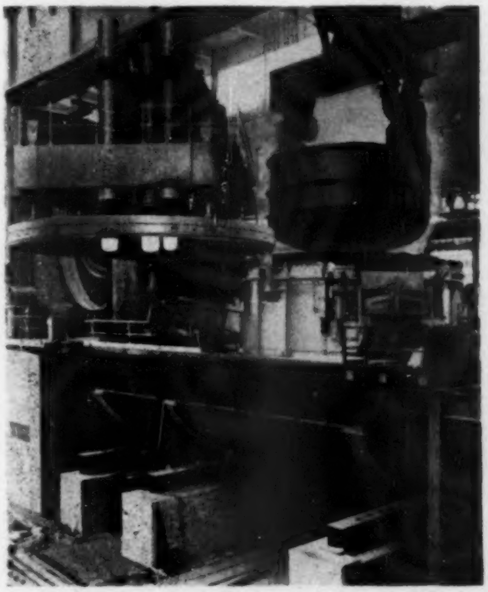
Tin in outer space

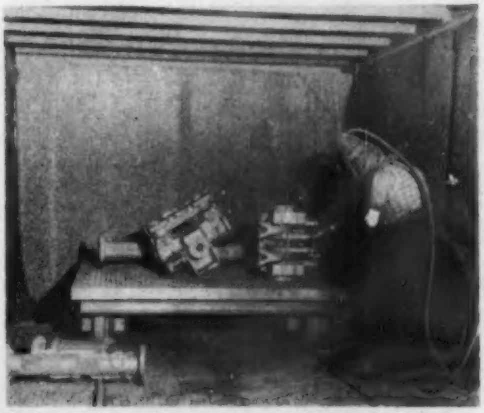
Alpha-titanium, containing 2·5% tin, is the structural material chosen for X-15, the first U.S. manned spaceship, according to *Tin News*, January, 1960. It would be manned by two or three men and orbit the earth at a speed of 18,000 m.p.h., returning gradually into the earth's atmosphere through the use of retro-rockets. Titanium, a metal refined from the ores ilmenite and rutile, has, in various alloys, the characteristics and properties of high-grade steel, but only 60% the weight. More than half the titanium used in jet aircraft is now in the form of an alloy, alpha-titanium, containing 5% aluminium and 2·5% tin. The addition of tin provides greater creep resistance.

Shot-blasting castings

The dressing shop serving the iron and non-ferrous foundries at the works of Lee, Howl & Co. Ltd., Tipton, Staffs., had become outdated and new premises have now been provided. The new shop is designed to handle 1,200 tons of castings a year, the weight of casting varying from a few ounces to 3 tons. Castings are for various pump parts and accessories.

One of the major items of new plant is a Spencer and Halstead shot-blasting cabinet, 15 ft. by 10 ft. by 8 ft. This plant is equipped with a magnetic separator under the floor, so that if required de-coring can take place in the cabinet. The larger size castings are brought from the iron foundry on a bogey mounted on rails, which terminate in the shot-blasting cabinet. Heavy castings are also handled in the shop by a 3-ton overhead runway chain hoist. The shot-blasting cabinet is fitted with a special glass roof and rubber-lined walls, which reduce noise and plate wear.





ABOVE *Interior of shot-blasting cabinet at Lee, Howl & Co. Ltd.*

LEFT *The 150-ton capacity electric arc furnace in the vertical position with roof swung to side for charging operations*

G.E.C. vacuum furnace for BISRA

The General Electric Co. Ltd., in association with Vacuum Industrial Applications Ltd., has received an order for the supply of a vacuum melting furnace to the British Iron and Steel Research Association for use in their Sheffield laboratories.

The furnace has a melting capacity of 56 lb. and is to be used for research into the vacuum melting and casting of ferrous metals. The working pressure of the furnace is 1μ Hg. and it is designed for a working temperature of 1,700°C.; the charge is poured into the moulds by tilting the crucible.

80-ton arc furnace for vacuum casting

In connection with a scheme for casting in vacuum ingots for forging, English Steel Corporation Ltd. has ordered from Birlec-Efco (Melting) Ltd. a 21-ft. diam. arc melting furnace.

The new furnace, with a nominal charge capacity of 80 tons, will be the largest in Britain. It is to be engaged on melting and refining high-grade carbon, alloy and stainless steels. Molten steel from the Birlefco arc furnace will be tapped into a ladle which, in turn, will form the closure of a vacuum ladle.

Dowson & Mason jubilee

Dowson & Mason Ltd. was formed in 1910, by the amalgamation of the Dowson Economic Gas & Power Co. Ltd. of London, with the Mason Gas Plant Co. Ltd. of Manchester.

The original Dowson Company was founded by J. Emerson Dowson, M.I.C.E., inventor of a simple producer gas generator for driving engines and heating applications, both domestic and industrial. At the York meeting of the British Association in 1881 Mr. Dowson read a paper and demonstrated the producer with a 3 h.p. Otto gas engine.

Taking his ideas from the heating of gas retorts, Mr. Mason invented 'Jennison's patent smokeless decker oven' and commenced manufacture in Longsight, Manchester, in 1870. The business was extended in 1897 by the introduction of the 'Duff gas producer,' which was suitable for furnaces, in addition to bakers' ovens.

The Mason business continued to develop and in 1904 moved into larger premises in Levenshulme—the present headquarters of the company. Extensions were carried out in 1914 and again in 1959.

Since 1900 the prime interest has been the construction of all types of industrial furnaces, and it is a source of pride that many large steel vessels in the atomic power stations have been stress relieved in Dowson & Mason furnaces, which include some of the largest in the world. In recent years many large Dowson & Mason stress-relieving furnaces have been built in the British Isles, Denmark, Portugal, South Africa, Australia, New Zealand, Brazil and Mexico.

Computer courses

The Morgan Crucible Co. Ltd. is sending about 50 of its managers on computer courses during the next six weeks.

To give a general understanding of the functioning of computers, arrangements have been made for International Computers & Tabulators Ltd. to run a two-day course for the managers likely to be involved in their use.

Executive directors also have recently attended a course on computers.

Corrosion Science Society

The founding of a Corrosion Science Society with the following immediate aims has been announced:—

1. To promote the advance of corrosion science and its application to the solution of practical problems.
2. To organize meetings—personal, local, national and international—of scientifically-qualified persons interested in all fields of corrosion and corrosion-protection research and practice, for the discussion of current work.
3. To co-operate with all other professional individuals, societies and institutes, British and foreign, with interests in the corrosion field.

The first meeting will be held on April 4-5, at Battersea College of Technology, London. Stress-corrosion cracking, the corrosion and protection of aluminium, cathodic protection, electrode processes and high-temperature corrosion and oxidation will be among subjects to be discussed on the basis of a series of talks by workers at present active in these fields. All interested should write to either Dr. T. P. Hoar, Department of Metallurgy, Pembroke Street, Cambridge, or Dr. L. L. Shreir, Battersea College of Technology, London, S.W.11.

Symposium in India

'Pilot plants in metallurgical research and development'

A symposium on 'Pilot plants in metallurgical research and development' is being held in the auditorium of the National Metallurgical Laboratory, Jamshedpur, from the 15th to 18th of this month.

Prof. M. S. Thacker, Director-General, Scientific and Industrial Research, New Delhi, inaugurated the symposium on Monday, February 15, Sir J. J. Ghandy, KT., C.I.E., Director-in-Charge, the Tata Iron & Steel Co. Ltd., and Chairman of the Executive Council, National Metallurgical Laboratory, presiding.

The object of the symposium is to focus attention on the application of pilot plants in metallurgical research and development and to emphasize on the utility of undertaking such pilot plant work in different aspects of metallurgical and mineral industries.

A large number of scientific and technical contributions, dealing with different aspects of pilot plants, have been received for presentation at the symposium from leading metallurgists and scientists both in India and abroad.

Last year's symposium

A symposium on *Iron and steel industry in India*, organized by the National Metallurgical Laboratory (Council of Scientific and Industrial Research), Jamshedpur, was held from February 4 to 7, 1959, when nearly 50 papers were presented. These have now been published with discussions in a bound volume by Technical Journals of India (Private) Ltd., 24 Brabourne Road, Calcutta, 1.

Powder metallurgy

Direct rolling processes

The Powder Metallurgy Joint Group of the Iron and Steel Institute and the Institute of Metals will hold an informal discussion on '*Direct rolling processes in powder metallurgy*' in the Hoare Memorial Hall, Church House, Great Smith Street, London, S.W.1, on Tuesday, April 12.

Liquefied petroleum gases

Increasing use is being made of liquefied petroleum gases in many applications of industrial internal combustion engines. The advantages offered by this type of fuel were demonstrated at Bingley Hall, Birmingham, last month, when Shell-Mex and B.P. Gases Ltd. arranged an exhibition of equipment by six major manufacturers.

The simplicity and speed of adaptation of conventional engines to L.P.G. operation were demonstrated with an actual conversion in the exhibition hall.

PEOPLE

THE DIRECTORS of Ambrose Shardlow & Co. Ltd. have pleasure in announcing that **Mr. Frank A. Perkins,** who is a director of the company, has been appointed chairman of the board, and **Mr. J. C. Proudfoot** has been appointed managing director of the company.

The Hadfields Group of Companies announces that at his own request, **Mr. T. H. Arnold,** M.B.E., F.I.M., has relinquished his appointments as local director and controller of the Research Department and also as a director of the subsidiary companies, Hadfields Steels Ltd., and Hadfields Forgings Ltd. The Board acknowledges with appreciation his loyalty and the good work he has done for such a long time.

Mr. Arnold joined the staff of the Chemical Laboratory of Hadfields Ltd., in 1915 and during 1920 was placed in charge of the Metallographic and Corrosion Laboratories. During the years 1920-1940 he was very closely associated with many of the researches of the late Sir Robert Hadfield, Bart., F.R.S. He carried out much original work into the constitution of manganese steel, in particular with respect to its applications to armour and parts of fighting vehicles.

He has been closely associated with the development of corrosion and heat-resisting steels, and has contributed much to the Iron and Steel Institute, and later, the British Iron & Steel Research Association's work on improved steels to resist atmospheric corrosion.

Mr. Arnold has been an active member of the Sheffield Metallurgical Association since he joined in 1923. He was awarded the M.B.E. in the Honours List of June, 1957, for his researches in ferrous metallurgy.

Mr. L. G. Finch, B.MET., PH.D., succeeds Mr. Arnold as local director and controller, Research Department. **Mr. J. A. Grainger,** M.ENG., has been appointed deputy research controller.

Mr. Herbert Slack has been appointed to the board of Kelvin & Hughes (Industrial) Ltd. as sales director. Mr. Slack was formerly technical sales manager.

In 1949 he joined Kelvin Hughes, and after a period of training at the Glasgow factory remained in Scotland to form a Technical Contracts Department for the company's industrial range of equipment. He was appointed a technical engineer and in this capacity later set up a service and erection organization and at the same time continued to build the Technical Contracts Department as the range of industrial equipment increased. In 1955 Mr. Slack took over the Kelvin Hughes industrial sales organization in the North of England and Scotland in addition to the Technical contracts Department.

The (American) National Association of Corrosion Engineers has announced that the Frank Newman Speller Award for 1959 has been bestowed on **Dr. J. C. Hudson,** D.SC., D.I.C., A.R.C.S., F.I.M., head of the British Iron and Steel Research Association's Corrosion Section.

The award is made annually in recognition of public contributions to corrosion engineering, and is a signal recognition of distinguished services to this branch of science.

Dr. A. M. Sage, PH.D., B.SC., development manager, Alloys Division, Union Carbide Ltd., has been elected a Fellow of the Institution of Metallurgists.

John H. Histed, a graduate of Cambridge University, has joined the staff of the Development Department, Alloys Division, Union Carbide Ltd.

Sir John Wrightson, Bt., T.D.

Mr. Richard Miles, chairman and managing director of Head Wrightson & Co. Ltd., retired at the end of last month. Mr. Miles, who has been chairman of the company for ten years and managing director for 25 years, remains on the board of the parent company.

Sir John Wrightson, Bt., vice-chairman, and managing director for the last ten years, has been appointed to succeed him as chairman and managing director.

Sir Alexander Fleck, K.B.E., F.R.S., who attained the age of 70 last year, has intimated his intention of relinquishing his position as chairman of the board of I.C.I. Ltd. and of resigning from the board of the company at the end of this month.

Sir Alexander will have been actively associated with the company and its predecessors for over 44 years. He was appointed a director of Imperial Chemical Industries Ltd. in 1944, and was elected a deputy chairman in 1950. He succeeded Mr. John Rogers, O.B.E., LL.D., as chairman on the latter's resignation in 1953.

The board have unanimously agreed to elect **Mr. Stanley Paul Chambers,** C.B., C.I.E., as chairman of the board, to succeed Sir Alexander with effect on and from March 1.

Mr. Chambers, who is 55 years of age, has been with I.C.I. Ltd. since 1947, when he was appointed to the board. He was elected a deputy chairman in July, 1952.

After taking a Master's Degree in Economics at the London School of Economics, of which he is now a governor, Mr. Chambers started his career in the Inland Revenue Department in 1927. In 1935 he was a member of the Indian Income-Tax Inquiry Committee and later acted as Taxation Adviser to the Government of India, during which time he became a member of the Indian Legislative Assembly and later of the Council of State; for his services in India he was created a Companion of the Indian Empire.

Returning to this country in March, 1940, Mr. Chambers was appointed Director of Statistics and Intelligence and Assistant Secretary to the Board of Inland Revenue. In 1942 he became Secretary to, and a member of, the Board of Inland Revenue; for his Inland Revenue work he was created a Companion of the Bath in 1942.

At the end of the war he was appointed Chief of the Finance Division of the British Element of the Control

Commission for Germany, which post he held until he left the public service to join the board of I.C.I. in 1947.

He has been a member of several Government Committees, and in 1953 he accepted an invitation by the Government to be the chairman of a Committee of Inquiry into London Transport.

Mr. Chambers is also a director of the National Provincial Bank Ltd., the Royal Insurance Co. Ltd., the Liverpool, London and Globe Insurance Co. Ltd., African Explosives and Chemical Industries Ltd. and several other companies, and is a part-time member of the National Coal Board.

Mr. A. Nadin, A.M.B.I.M., A.M.I.W.M., was appointed general manager, with effect from January 1, of Brayshaw

Mr. A. Nadin

Furnaces Ltd. and Brayshaw Tools Ltd., Belle Vue Works, Manchester, 12.

Mr. Nadin, a native of Sheffield, was prior to his appointment as works manager with the Brayshaw companies in 1957, connected with Samuel Osborn & Co. Ltd., Sheffield, and their subsidiary companies.

Dr. George Macfarlane, a deputy chief scientific officer at the Royal Radar Establishment, Malvern, has been appointed deputy director of the National Physical Laboratory. He succeeds Dr. Edward Lee, who becomes director of Stations and Industry Divisions at the Department's headquarters.

Dr. Macfarlane, who is 43, graduated with first-class honours in electrical engineering at Glasgow University in 1937, and went on to do two years' post-graduate research at Dresden, when he gained the Dr.Ing. degree in 1939. He joined the Telecommunications Research Establishment (now incorporated in R.R.E.) in 1939.

Throughout the war years Dr. Macfarlane concentrated on mathematics problems in radar and micro-wave physics. In 1945 he became head of the Mathematical Group, and a year later took charge of the Theoretical Physics Division. Since 1953 he has been carrying out individual research in the Physics Department.

Dr. Edward Lee was educated at Consett Grammar School and graduated at Manchester University with first-class honours in physics. After taking his M.Sc. at Manchester University and his Ph.D. at Cambridge University, he joined the Royal Naval Scientific Service in 1939 and was posted to the Admiralty Research Laboratory.

In 1946 Dr. Lee joined the Defence Research Policy Staff at the Ministry of Defence, and from then until 1951 his work was mainly concerned with relating Service research programmes to the scientific effort available and Service requirements. He was director of Operational Research at the Admiralty for three years before becoming deputy director at the National Physical Laboratory in March, 1958. He took up his new duties as director of Stations and Industry Divisions at the beginning of the year.

Brigadier H. P. Crosland, C.B., C.B.E., M.C., T.D., D.L., chairman and managing director of Metal Traders Ltd., has been elected chairman of the Zinc Development Association for 1960. The former chairman, **Mr. R. T. de Poix,** O.B.E., will continue as a member of the Council of the Association.

Mr. J. A. Goddard, director and secretary of Fry's Diecastings Ltd., has been elected chairman of the Zinc Alloy Die Casters Association for 1960. He succeeded **Mr. K. J. Whitehead,** joint managing director of Wolverhampton Die Casting Co. Ltd.

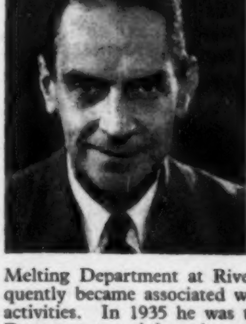
Sintered Products Ltd. announces the appointment of **Mr. Joseph Greatorex** as chief inspector.

Mr. Greatorex, an associate member of the Institute of Engineering Inspection and a licentiate of the Institute of Metallurgists, has been with the company since he completed his military service in 1953. During that period Mr. Greatorex has progressed from laboratory assistant to assistant metallurgists, and subsequently from works metallurgist to head of the inspection department. This advancement has given him considerable experience in quality control at all stages of the various production processes involved in modern powder metallurgy.

Dr. H. **H. Burton,** C.B.E., has retired from the board of directors of English Steel Corporation Ltd. Dr. Burton will continue as research consultant to the Group until the end of the year.

Mr. T. R. **Middleton,** B.SC., F.I.M., has been appointed a director of English Steel Corporation Ltd. and director of research.

A former pupil of King Edward VII School, Sheffield, Mr. Middleton graduated from Sheffield University with the degree of B.Sc. He joined Cammell Laird & Co. Ltd., Sheffield, in 1922, and after periods in the Chemical Laboratory and Research Department became manager of the Tool Steel Melting Department and later assistant manager of the Steel Department at Cyclops Works. When English Steel Corporation Ltd. was formed in 1929, he was appointed assistant manager of the Electric



Mr. T. R. Middleton

Melting Department at River Don Works, and subsequently became associated with a variety of production activities. In 1935 he was transferred to the Research Department and has since acted as a principal in all aspects of the Corporation's metallurgical work.

He is a Fellow of the Institution of Metallurgists and a member of various technical committees.

INSTRUMENTATION

British instruments exhibition in Russia

As a result of the report to the Council by the three-man delegation of the Scientific Instrument Manufacturers' Association of Great Britain, SIMA House, Queen Anne Street, London, W.1, which went to Moscow last November, and the support from 30 members of SIMA, an exhibition of British scientific instruments will be held in Moscow from June 16 to 26, 1960. This exhibition will be the first to be put on in Russia by a British organization of manufacturers in a specialized field.

New tester measures cleanliness

Developed by the Graham Research Laboratories of Jones & Laughlin Steel Corporation (Pittsburgh, Pa.) and built by Branson Ultrasonic Corporation (40 Brown House Road, Stamford, Conn., U.S.A.) under a licensing arrangement, a new tester makes it possible to assign numerical values to surface cleanliness where non-bonded soils are involved.

For example, the Model CM-1 will measure smut residue after pickling of steel. In addition, the tester may be used to evaluate: (1) detergents and oils used on cold mills; (2) annealing furnace performance; and (3) efficiency of electrolytic and alkaline cleaning lines.

The tester has a linear scale from 0 to 1,000, where 1,000 indicates absolute cleanliness. Accuracy of one part in a thousand is made possible by a ten-turn potentiometer in the balancing circuit. The test is more exact than methods formerly used, such as the water-break and wipe tests.

Testing involves only two steps:

(1) Soil is removed from the surface under test with transparent, pressure-sensitive tape, which is then affixed to a 25 × 75-mm. microscope slide.

(2) Optical density of the composite (tape, soil and slide) is measured by the tester, which is actually a densitometer designed specifically for that purpose. Readings are direct and give a numerical value for cleanliness.

The Branson cleanness tester

New bellows flowmeter

A new bellows-type flowmeter featuring automatic temperature and static pressure stabilizing is introduced by Honeywell Controls Ltd. It is claimed to be the most stable in operation of its kind yet developed.

The new flowmeter will operate efficiently with ambient temperatures between −40°F. and +250°F., and it incorporates a rapid pulsation damping device.

The instrument, which is suitable also for liquid-level measurement, has an accuracy of ±0·5% full-scale differential pressure. Positive overload protection is provided. Fifteen different ranges from 0—20 to 0—400 w.g. are available; only the simplest component change is necessary for range changing. A large bellows system and torque tube assembly give high torque and power output for the operation of additional elements.

The flowmeter can be used in conjunction with

Early English pyrometer

Newest acquisitions of Smithsonian Institution in Washington, U.S.A., are early pyrometers—developed by English emigrant Edward Brown for measuring high temperatures. Examining an 1884 model are Mr. Richard P. Brown, of Philadelphia, the inventor's son (left), and Dr. Leonard Carmichael, secretary of the museum. On the table is a modern version having automatic control action.

The presentation was made by Mr. Brown on behalf of the American associates of Honeywell Controls Ltd. Mr. Brown and his father helped pioneer the international Honeywell organization.

NEW PLANT

Drop-forging innovations

B. & S. Massey Ltd. have recently introduced three new developments in the drop-forging field. These are: (1) footlever guards for pneumatic power hammers; (2) nylon lifting belts for friction drop hammers; and (3) friction band linings and hold-up band linings for drop hammers.

(1) During the many years B. & S. Massey Ltd. have been supplying pneumatic power hammers, they have occasionally heard of accidents that have been brought about by the inadvertent operations of the footlever, or by a workpiece falling from the lower pallet. In an attempt to prevent such accidents various guards were made; these, however, were not completely successful, as they either impeded the operator's access to the pallets or prevented complete freedom of the foot when operating the footlever.

The guard shown in fig. 1 overcomes these difficulties. It has been in practical use in the smithy of B. & S. Massey Ltd. for a number of months and it has proved entirely satisfactory.

(2) Prior to nylon becoming a commercial proposition, the use of woven-hair lifting belts was general practice in the drop-forging industry. For a number of years now B. & S. Massey Ltd. have been subjecting nylon lifting belts to severe drop-hammer tests, under actual forge conditions. The earlier type of nylon belt proved to have too great a stretch, but the manufacturers have now devised a belt that is superior in every way to the woven-hair belt originally used. Some users have reported that this nylon belting has lasted for more than five years.

(3) In the early post-war years the manufacturers of friction brake linings began to use new materials which made their product less suitable for friction and hold-up bands, particularly those of the self-contained and Marathon hammers, where the drum diameter is less. Following a number of band failures, B. & S. Massey instituted an investigation into the matter, and are now able to offer linings which have passed a most stringent test under working conditions.

1 *Footlever guard for Massey pneumatic power hammers*

2 *Interlas plate-lifting clamp*

Plate-lifting clamp

Interlas plate-lifting clamps are now available in the United Kingdom in seven different sizes to accommodate loads of 1½ tons maximum to 20 tons maximum, and plate thicknesses of ⅜ to 3 in.

Safe transportation of plates held in the vertical position is desirable in every steel stores, yard and engineering shop, and is absolutely essential when movement along narrow gangways and passages is required. Interlas clamps are designed to lift plates or fabricated plate sections without danger of the load slipping. The greater the pull, the tighter the cam-operated jaws grip the plate, and even when the weight of the plate is taken on the ground, the clamp cannot loosen until the locking lever has been released. When the clamp has been released it can be pulled away easily, as there are rollers which run on the plate. Such is the safe powerful grip of the clamp that a plate can be raised from horizontal to vertical or lowered from vertical to horizontal in complete safety.

Interlas N.V., of Holland, were the originators of the double cam-operated lifting clamp, and they have supplied thousands of them to shipbuilding and general engineering firms on the Continent. Now the full range is available from the British associates, Interlas Ltd., 9 Church Street, Ampthill, Bedford.

Radical development in balances

The first of a new series of balances designed for general purposes but incorporating analytical features has been produced by Griffin & George Ltd., Ealing Road, Alperton, Wembley, Middlesex. It is the Griffin 'Minor' balance, the result of nearly a century and a half of experience in this field.

The Griffin 'Minor' has a short beam for speedier weighing; single-limb bows carrying the weighing pans for unimpaired operation; an inclined scale which rises with the pointer, thus facilitating reading and avoiding parallax; a unique design in stirrups to protect knife edges; and a new design pillar allowing easy and rapid assembly.

The improved assembly of the agate bearings is extremely important because they are held in position by

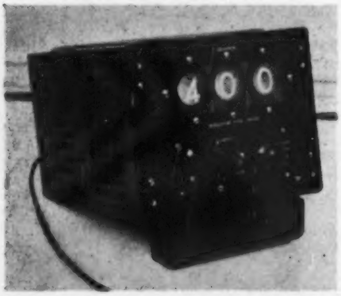
integrally mounted or remote reading indicators, recorders or controllers. Automatic flow totalizing on a six-digit counter can also be incorporated.

The bellows and all parts of the bellows assembly exposed to the process fluid are of stainless steel, making the flowmeter suitable for use with almost any process fluid. Ease of installation is assured by pressure connections for vertical and horizontal piping which can be positioned at either the top or the bottom with no change of parts.

Digital voltmeter

Almost every physical quantity can now be converted electronically into an electrical voltage. To read-off these voltages to three-figure accuracy with *certainty* of the third figure often proves impossible with conventional meter dials and charts.

The new Solartron '999' digital voltmeter Type LM 901 eliminates this uncertainty by displaying the



Solartron digital voltmeter

measured voltage in large, plain figures, which may be read at considerable distance from the instrument and, if necessary, by untrained personnel.

Manufactured by the Solartron Electronic Group Ltd., Thames Ditton, Surrey, the LM 901, being transistorized, is lightweight and of compact construction. It is completely self-contained, and its power consumption is extremely small.

The voltage range is from zero up to 99·9 V. in three sub-ranges, or 109·9 V. when using the range extension facility. The measured voltage is continuously monitored and the readings change with any variation.

Automatic dewpoint recording controller

The measurement of dewpoint as a ready estimate of the 'carbon potential' of suitable furnace atmospheres is now very widely accepted as a practical means of controlling such operations as carburizing, carbo-nitriding and carbon restoration. Suitable instruments for spot checks are in wide use, but continuous recording allied with automatic control of furnace atmosphere requires an instrument with quick response, high accuracy and reliability. The Ipsen Dewtronik, now made available in this country, has been developed to meet this specification.

Approximately 25 c.f.h. of the atmosphere under test is drawn by a specially developed pump through a properly designed sampling and filtering system, supplied with the instrument. The sampled gas passes over the glass-insulated face of a bar cooled by a refrigerating system; two platinum electrodes on the exposed glass face are connected to the 'Dewtector,' an electronic device which applies suitable potential to the electrodes and 'senses' any moisture film immediately it develops. Formation of 'dew' triggers a relay and turns on heaters built into the 'sensing head.' Dispersion of the dew cuts out the heater and the design is such that, in operation, the sensing head face is maintained within 2°F. of the true dewpoint of the sample gas.

A thermocouple with junction adjacent to the electrodes signals the prevailing dewpoint temperature to a standard indicating and recording potentiometer. Mercury switches in this instrument act according to the preset required atmosphere dewpoint to operate suitable solenoid valves in additive gas lines or motorized ratio controllers, thereby maintaining furnace or generator atmosphere dewpoint within very close limits.

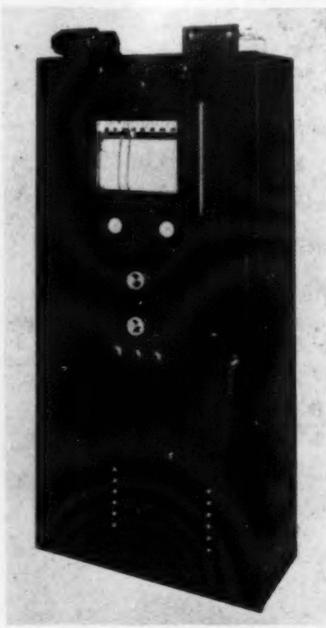
The operating range of 0–90°F. (or ambient temperature) covers most requirements in this field.

The instrument and accuracy are completely unaffected by all normal atmosphere constituents including ammonia. Reliability rather than economy has been studied in the specification and construction and only a very little unskilled maintenance is required. The fact that the instrument is functioning correctly can be determined at a glance at any time, due to the rapid cycling action in normal operation.

Immediately after loading a batch furnace, very moist atmosphere must prevail for a short period, and a standard built-in delay timer arranges for the automatic cessation and resumption of sampling to avoid the system being saturated in this brief period.

Built as a compact unit of good appearance, the Dewtronik is available as a single recording controller or dual recording controller. The latter, illustrated above, samples, records and controls two furnaces, two zones of one furnace, or furnace and generator. The speed of response of the instrument makes it possible to supply as further alternatives, either 4-point or 6-point recording instruments.

Ipsen Inc. is represented in the U.K. by Mr. T. W. Ruffle, 53 Victoria Road, Surbiton, Surrey.



Dewtronik dewpoint recorder

positioning screws instead of being 'drifted in' which is the usual practice. When the beam is arrested all the agate bearings are relieved. Usually only the central bearing is. This gives much longer life with students and in works control laboratories.

This new balance is a well-built, accurate and inexpensive instrument with a modern appearance.

Vertical cylindrical closed-quench furnace

A new atmosphere furnace combining the advantages of pit-type gas carburizers with facilities for closed quenching, hitherto available only in horizontal equipments, is announced by the Electric Resistance Furnace Co. Ltd. This new furnace does not supersede the well-proved Efco-Lindberg horizontal furnaces, but for some types of charges, particularly dense loads of parts having internal bores and long components, it offers distinct advantages.

The furnace has a vertical cylindrical heating chamber which is closed at the top and has provision for the insertion of a charge through the base. The furnace is electrically heated by Corrtherm elements or gas fired with radiant tubes. The charge is shielded from direct radiation by a heat-resisting baffle suspended from the furnace roof or, alternatively, the sides of the charge basket. A powerful fan of large diameter, mounted directly above the charge, draws the atmosphere up through the charge and forces it down over the heating elements, ensuring uniformity of heating and intimate contact of the atmosphere with all surfaces of the charge.

Because of its cylindrical shape the chamber accommodates a larger volume of work within a smaller wall area and operates at greater efficiency than an equivalent horizontal rectangular furnace. An economy in gas or electricity consumption of the order of 15% is effected. Atmosphere consumption is reduced due to the smaller volume of heating chamber to be purged. The mouth of the heating chamber and bung are designed to form a heat trap.

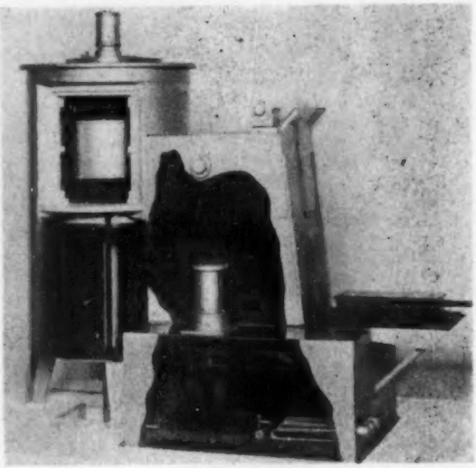
The work, normally in a nickel-chrome basket, is moved into the furnace through an outer, vertical rising door to enter the purging vestibule. Here it stands on one of the two platforms of the quench elevator. At the outer door a gas curtain automatically prevents ingress of air when the door is open. Both the door and the quench elevator are pneumatically operated. After purging, the charge is transferred to the furnace bung where it is supported on suitable stools which allow free circulation of the atmosphere.

A feature of the furnace is the use of a charge trolley to move the charge horizontally from the outer loading table into the purging vestibule and to and from the furnace bung. The trolley runs on rail tracks and is fitted with wheels which are mounted on ball bearings and carried in an articulated frame to ensure easy movement. Built into the trolley is a raising and lowering mechanism operated from outside the furnace with a removable push rod. The trolley can be moved in and out of the furnace without raising the outer door, a swinging counter-balanced flap attached to the outer door being provided for this purpose. After charging, the trolley is lowered and withdrawn.

The use of the trolley obviates the need for hearth rollers and, apart from the fan, no mechanical parts are subjected to furnace temperatures.

Stops are provided to ensure accurate location of the charge on the quench elevator and on the furnace bung which is raised hydraulically to lift and seal the charge into the heating chamber.

The charge is removed from the chamber by lowering the bung and transferring to the quench elevator by means of the charge trolley. When it has been lowered into the integral quench tank the outer furnace door can be raised and a new charge inserted.



3 *The Efco vertical closed-quench furnace*

The purging vestibule and the space beneath the heating chamber are water cooled. The quench tank of adequate capacity is fitted with oil pre-heaters, a multi-tube water cooling system, and a two-speed reversible agitator and baffle arrangement to direct a large volume of oil over the charge being quenched. The agitator, its driving motor and the cooling system, are mounted on a removable top plate for easy access for maintenance. The furnace can also be supplied with a hot oil quench tank for marquenching, which is of larger capacity and fitted with special air-cooled tubes.

When electrically heated the furnace chamber is fitted with patented Corrtherm elements which are sheets of corrugated nickel-chrome covering almost the entire wall. The life of the elements is not affected by soot deposition from hydrocarbon gas because the voltage and watts dissipation are so low that leakage across the deposit is negligible.

When gas fired, specially designed radiant tubes are positioned around the walls of the heating chamber. For easy maintenance the roof of the furnace chamber is removable and gives access to the fan and the elements or radiant tubes.

Atmospheres for the carburizing and carbonitriding processes are obtained from an Efco endothermic generator operating on town's gas or liquid petroleum gas.

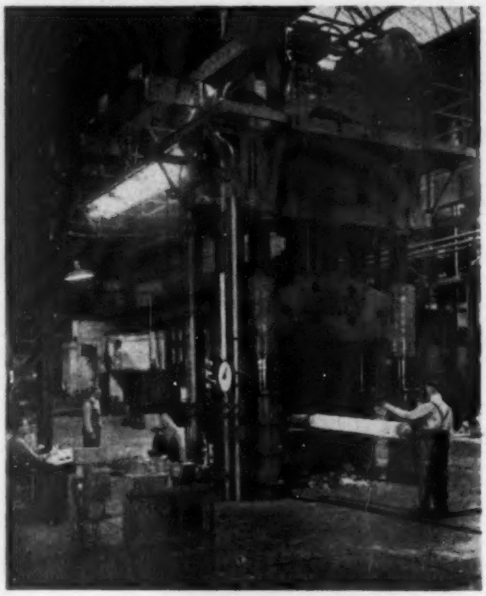
New high-strength concrete

The Lafarge Aluminous Cement Co. Ltd. announce a new synthetic aggregate for use with Ciment Fondu high-alumina cement, the resultant concrete attaining superlative qualities of density, hardness and strength in 24 hours and it is also heat resistant.

The new product, called 'Alag,' in some respects resembles a crushed basalt aggregate, with a chemical affinity for high-alumina cements.

'Alag' is dense, non-absorbent and extremely hard, with a hardness of 7·0–7·5 mohs (between quarts and topaz) which will cut glass. The concrete is able to withstand temperatures up to 1,200°C.

Firth-Brown forge development scheme



The 800-ton press in operation

THE FORGE DEVELOPMENT scheme, started in 1953 by Thos. Firth & John Brown Ltd., of Sheffield, with the purchase and installation of a 1,750-ton press, with all the necessary furnaces, including a 15-ton rail-type manipulator, is now stated to be working satisfactorily. Following the completion of the 1,750-ton scheme, a new shop was built for the installation of a new 800-ton press, equipped with a 3-ton mobile manipulator, and with furnaces of the most modern design. The press is being fitted with automatic precision control.

Next stage in this development scheme is the installation of a new 4,000-ton press, following the acquisition of the premises of W. Griffiths & Sons Ltd. in Brightside Lane, Sheffield. The extra room will enable the new press, due for operation by early 1961, to be installed while the old one is still working. The furnaces in this shop were of the old hand-fired type, and conversion of these to modern producer-gas furnaces will be completed by the time the new press is ready for work.

The extra room acquired, amounting in all to 5,500 sq. yd., will allow extension of the 1,000-ton press bay, where three new presses are also planned.

800-ton press

The press, which is 26 ft. overall height, is capable of exerting a force of 800 tons through a ram supplied with water at a pressure of 4,250 lb./sq. in. The daylight or clear opening of the press is 9 ft. with a working stroke of 4 ft. The cross-head which carries the top tool is capable of exerting the full 800 tons force at a steady speed of 6–8 in./sec. or, alternatively, can be made to give light planishing strokes at the rate of 120/min. to finish the surface of the material under the press.

The press is controlled by an operator at a control desk with servo-operated control valves giving accurate control with the minimum of effort; physical fatigue is eliminated and the number of quick forging strokes can be considerably increased.

Power for the press is supplied by three-throw horizontal pumps driven by 550-h.p. electric motors delivering 132 gal./min. at a pressure of 4,250 lb./sq. in. to a set of air-hydraulic bottles which form a reserve accumulator for the system.

The ingots or billets to be forged are heated to between 1,150 and 1,250°C. in six furnaces arranged by the side of the press. Two of the furnaces are heated by town's gas and the others by producer gas. A particular feature of the furnaces is the provision of automatic temperature and pressure control which automatically brings the pieces to be forged to the precise temperature required.

When the ingots or billets have been heated to the correct forging temperature, the bogie on which they are placed is withdrawn from the furnace and the material is picked up by a 3-ton manipulator driven by its own diesel engine weighing 20 tons. The manipulator takes the workpiece swiftly to the press, where the operator and manipulator driver work in conjunction under the direction of the forgeman to shape the ingot into its final shape and size.

If a particularly long forging is to be handled under the press, the manipulator is assisted by a 10-ton semi-Goliath crane, which carries the end of the forging on the opposite side of the press to the manipulator, by means of a turning-over gear operating a burden chain, supporting the outer end of the forging. In this case, the crane driver, press operator and manipulator driver have to work in unison under the direction of the forgeman, and it will be appreciated that the whole operation is essentially one of team work.

Classified Advertisements

FIFTEEN WORDS 7*s*. 6*d*. (minimum charge) and 4*d*. per word thereafter. Box number 2*s*. 6*d*. including postage of replies. Situations Wanted 2*d*. per word.

Replies addressed to Box Numbers are to be sent, clearly marked, to Metal Treatment and Drop Forging, John Adam House, John Adam Street, London, W.C.2.

SITUATIONS VACANT

INDUSTRIAL GAS REPRESENTATIVES

With the increase in the development and utilization of gas for industrial purposes, further appointments are being made in the Midlands to meet the demand.

The work will involve investigation and submission of schemes for the use of gas for furnace heating and other industrial purposes.

Applications are invited from candidates with an appropriate university degree, or similar qualification. Experience of industrial gas is not essential, as adequate training will be given.

The salary during the training period will be within the range of £733—£813 per annum and, subject to satisfactory completion of training, appointment to a permanent post on a higher grade will be made. The appointments are pensionable and subject to medical examination.

Applications, stating age, education, qualifications and experience, should be addressed to the Industrial Relations Officer, West Midlands Gas Board, 6 Augustus Road, Edgbaston, Birmingham 15.

METALLURGIST. With wide works experience for control and development of production heat treatment. Experience of atmosphere control and gas carburizing an advantage. Salary according to experience, contributory pension scheme. Apply: Heat Treatment & Brazing Co. Ltd., Hersham Trading Estate, Walton-on-Thames, Surrey. Tel.: Walton-on-Thames 20576.

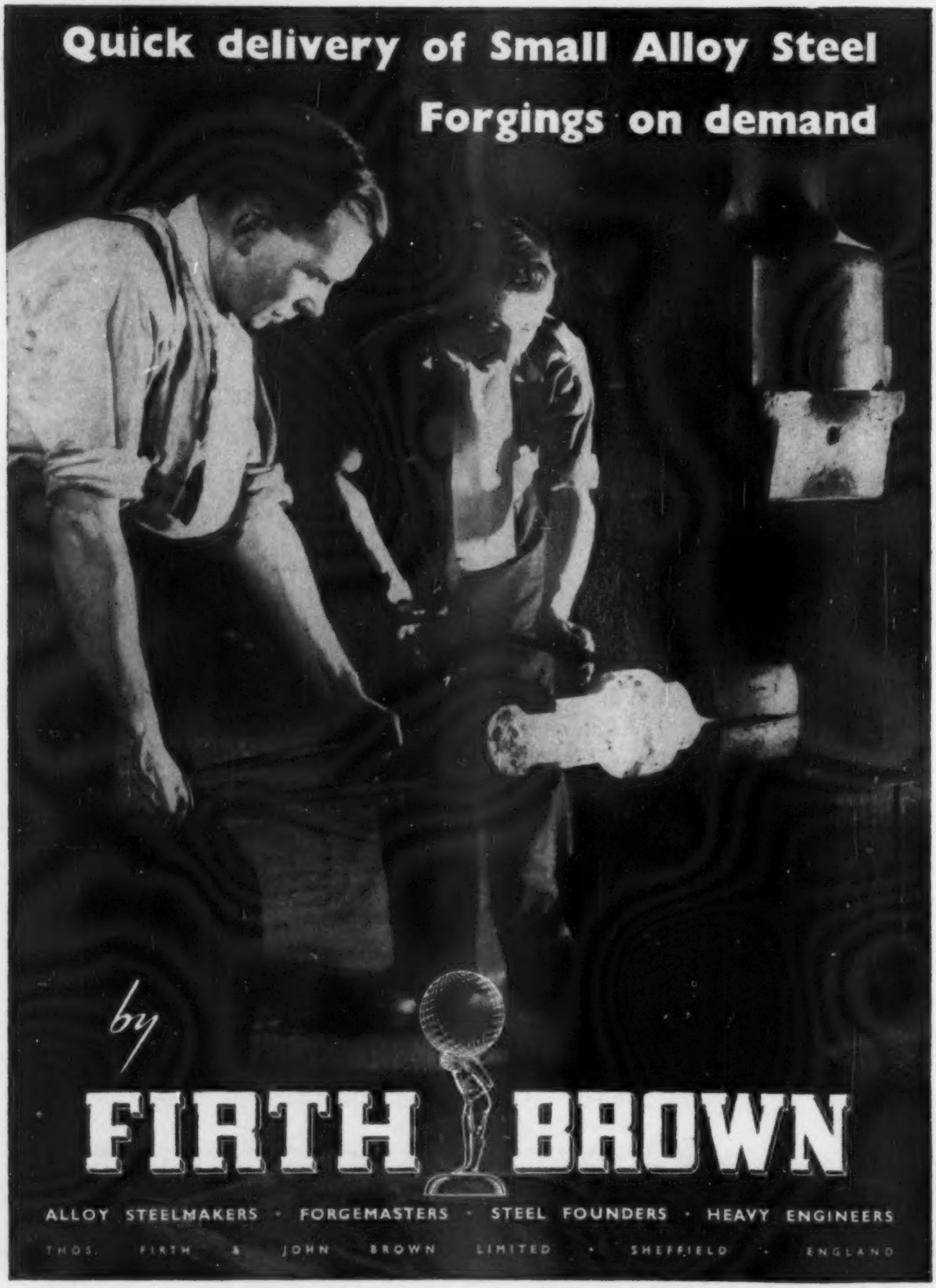
MACHINERY WANTED

MODERN, SECONDHAND, MASSEY, SELF-CONTAINED FRICTION DROP STAMP wanted, 20 to 40-cwt. capacity. Box MS124, METAL TREATMENT AND DROP FORGING.

URGENTLY REQUIRED.—Second-hand 25/30-cwt. Friction Drop Hammer. Poppet-type base. Massey or Brett. Full details.—Box UR125, METAL TREATMENT AND DROP FORGING.

FOR SALE

SAMUEL PLATT 800-LB. MOTORIZED FRICTION BOARD DROP HAMMER for sale. Length of drop 5 ft. Between uprights 14 in. Size of anvil 17 in. x 31½ in. Electrical equipment for 400/440/3/50. Weight about 10 tons. F. J. Edwards Limited, 359 Euston Road, London, N.W.1, or 41 Water Street, Birmingham 3.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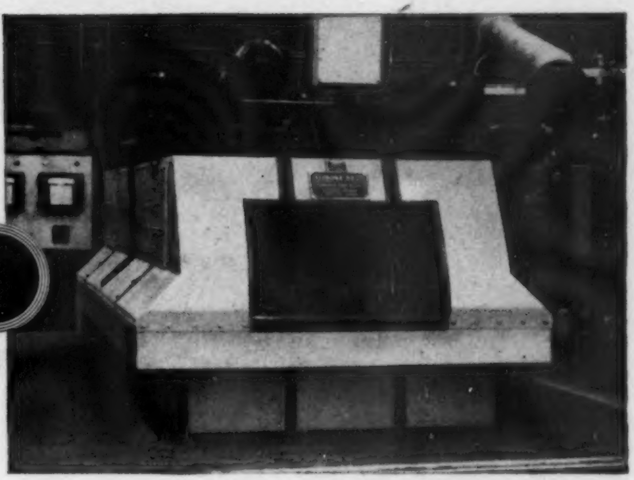

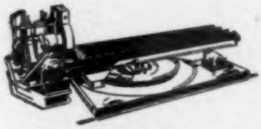

The Gibbons-van Marle Charging Machine is a natural complement to the Gibbons Quenching Machine.

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This essentially reliable machine, perfected over an extended period, is one of the most advanced units of its kind.

SAFETY

The canopy door opens and closes automatically, sealing off the quenching tank. Fire hazards and the steam nuisance are eliminated.

EFFICIENCY

Automatic load washing by oscillation. Drive units are robust and there are no complicated mechanisms to give trouble. Control by push-button.

'B-W' FURNACES...

Photograph by courtesy of Faulkners Ltd., Slough

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The 'Barlow-Whitney' range includes Vertical Loading Furnaces with Forced Convection for solution treatments, secondary hardening, annealing, tempering and ageing processes.

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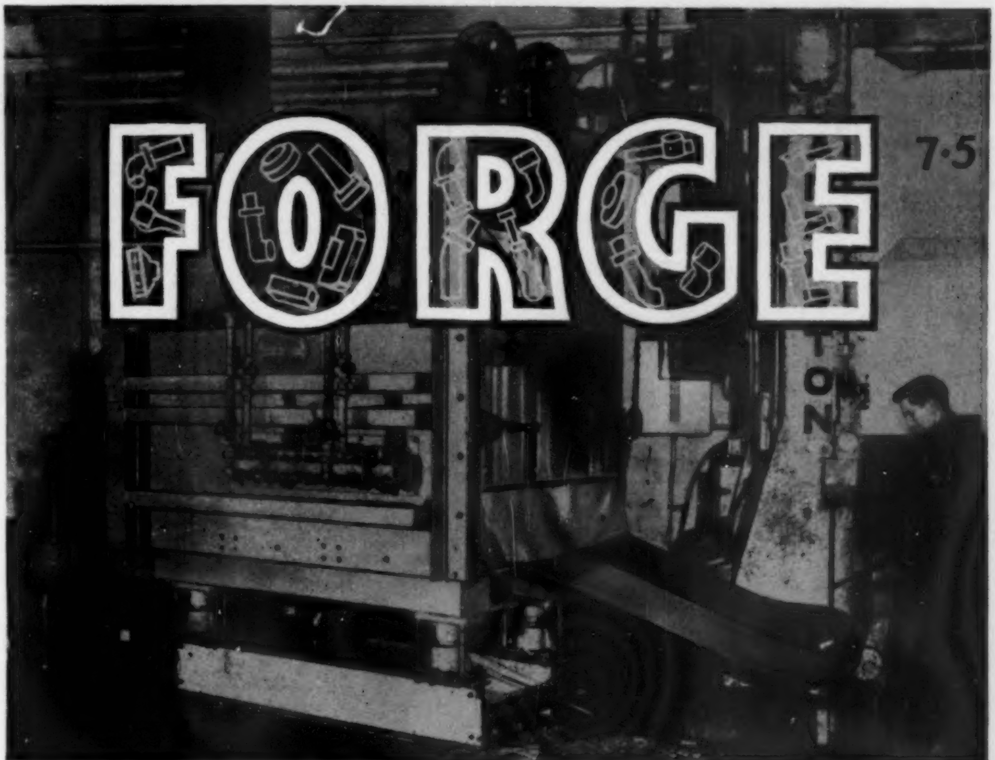
THERMIC

Mechanised



(Photograph by kind permission of the Austin Motor Co. Ltd.

FURNACES

A wide range of standard or tailor-made mechanised forge furnaces is available, Pusher Type - Rotary Hearth Type - Conveyorised Bar End Heating, with GGC scale-free heating system or fired by gas or oil. The photograph above illustrates a small Thermic Magazine Feed Pusher furnace fired by CC Burners. Output: 7-cwts. of small billets per hour.

Thermic Equipment & Engineering Co. Ltd.

(Subsidiary Company of Gibbons Bros. Limited, Dudley)

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